Weeds

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Weeds

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Table of Contents

	Page
Some Quantitative Aspects of Weed Competition in Vegetable Crops. C. A. Shadbolt and L. G. Holm	111
Some Effects of 2,4-Dichlorophenoxyacetic Acid upon Azotobacter as Measured by Respiration Inhibition. Lyman A. Magee and Arthur R. Colmer	124
Factors Affecting the Herbicidal Action of Aqueous Sprays of Salts of 4,6-Dinitro-ortho-secondary Butyl Phenol. William F. Meggitt, R. J. Aldrich, and W. C. Shaw	131
Some Factors that Influence the Effectiveness of 2,4,5-Trichlorophenoxyacetic acid in Killing Mesquite. C. E. Fisher, C. H. Meadors, and Richard Behrens	139
The Effect of the Application of Varying Rates of CMU at Different Stages of Plant Growth and Fiber Development on the Yield and Fiber Quality of Irrigated Upland Cotton. E. H. Everson and H. F. Arle	148
The Use of Herbicides in Establishing Legume Seedings. Paul W. Santelmann, Evert O. Burt, and C. J. Willard	156
Chemical Control of Big Sagebrush and its Effect upon Production and Utilization of Native Grass Species. H. P. Alley	164
Sodium Trichloroacetate—Centipede Grass Killer. C. B. Owens	174
News and Notes	177
Sustaining Members	179
Constitution of Weed Society	181
Index Volume I	185
Index Volume II	189
Index Volume III	193

Advertisers Index

Carbide and Carbon Chemicals Co.	ii
du Pont de Nemours & Co.	iii
Standard Agricultural Chemicals Inc.	iv
Chipman Chemical Co.	v
Diamond Alkali Co.	vi
American Cyanamid Co.	vii
Spraying Systems Co.	viii

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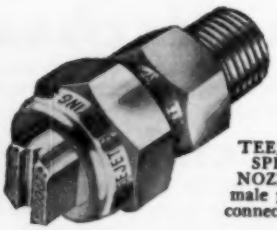

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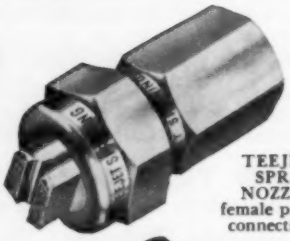

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Weeds

JOURNAL OF THE WEED SOCIETY OF AMERICA

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Some Quantitative Aspects of Weed Competition in Vegetable Crops[1]

C. A. SHADBOLT and L. G. HOLM[2]

THE tremendous losses brought about by the presence of weeds in agricultural crops have been much underrated in the past. Recently it has been estimated, probably conservatively, that the total losses to agricultural producers in the United States approaches four billion dollars annually (18). Unless the basic causes of these losses and the places in which they occur can be determined, their significance cannot be fully evaluated.

When plants are grown in competition with one another, several factors of the environment may be altered which will adversely affect the growth processes of the plants. The most important of these factors are: light intensity, soil moisture, and soil nutrient. It is extremely difficult under conditions of actual competition to determine the role which each factor plays in the injury to the crop. There is seldom only one factor involved, but more often there is a complex interaction between factors.

Under normal conditions of plant growth, for instance, the light intensity may be severely reduced. It has been determined that these reductions were greater than 90 per cent under alfalfa, soybeans and rye (21), 70 to 80 per cent under an oat cover crop (4), and from 30 to 95 per cent in various locations of an apple tree (6).

Weeds may also interfere with the uptake of nutrients from the soil. Mann and Barnes (8, 9, 10, 11) have shown that certain weeds when grown in competition with barley were able to take up nitrogen at the expense of the crop. Similarly, Blaser and Brady (3) found that many weeds were better able to absorb potash from the soil than forage grasses and legumes.

During the summers of 1952 and 1953, experiments were conducted at the University of Wisconsin to determine quantitatively the effects of weed competition on vegetable crops. A study was made

[1]This material is taken from the senior author's thesis presented to the Graduate School of the University of Wisconsin in 1955 in partial fulfillment of the requirements for the degree of Doctor of Philosophy. It is published with the approval of the director of the Wisconsin Agricultural Experiment Station.

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of the degree of injury resulting from several levels of weed population and the permanency of this injury when the competition was removed. This information was obtained by allowing controlled numbers of weeds to compete with the crop for various periods of time. It was possible by this method to determine the effects on the crop at the end of the competitive period, as well as the degree to which these plants recovered when the competition was removed.

The principle purpose of this study was to measure quantitatively some of the effects of weed competition on several vegetable crops. Attempts were also made in a few instances to diagnose the basic causes or reasons for these effects. The greatest emphasis however, was focused on the degree and the type of injury resulting from several weed concentrations in competition with the crop for known periods of time.

METHODS AND MATERIALS

Experiments to determine the effects of weed competition on carrots, onions and beets were conducted at Madison, Wisconsin during 1952 and 1953. All trials were carried out on an organic soil which was relatively high in soil moisture throughout the growing season. The fertility level of the soil was raised to that recommended for vegetable production by the addition of a complete fertilizer. Precautions were taken to prevent the infestation of diseases and insects. Randomized complete blocks with 4 replications were used except in the case of beets. The data were examined by the analysis of variance.

The three crops, carrots (var. Chantenay, Red Cored), onions (var. Downing Yellow Globe), and beets (var. Detroit Dark Red), were sown in 12 foot single row plots early in May with 40-inch spacing between the rows. An uncultivated band 8 inches wide was left over the rows. The experimental area was found to have a reasonably uniform weed population of about 20 weeds per square foot. By careful hand thinning any desired weed population could be obtained. Twenty, 50, and 100 per cent of this stand was used in 1952, and 15, 30, and 50 per cent in 1953. Red root pigweed, *Amaranthus retroflexus* L., water hemp, *Acnida* sp. and ladysthumb, *Polygonum persicaria* L. predominated in the experimental area. In order to achieve maximum experimental control, the first two species were retained whenever possible. These controlled weed stands were allowed to remain in competition with the crop for the desired length of time after emergence, and were then carefully removed. The weight of weeds was recorded at this time. The experiments were arranged in such a manner that measurements of the weight and size of the crop plants were obtained at two periods: 1) when the weeds were removed early in the season, and 2) in the fall after the crop plants had matured free from further weed competition. The extent of the injury at the early harvest was compared to the injury still remaining in the fall, and in this manner the extent of the recovery of the crop from initial injury was determined.

In 1952, the three dates of weed removal were at 4, 5½, and 7

weeks after emergence of the crop. Measurements were made on the carrot plants at these times, and it was found that at the later dates the injury to the crop was excessive, even at the lowest level of weed population. In 1953, therefore, the weeds were removed at 3½, 4½, and 5½ weeks after emergence. All of the individual plant measurements were taken on a sample of 32 plants selected at random from the entire plot.

The area of the carrot and the beet leaves was measured by an optical planimeter; an instrument especially constructed for the measurement of flat surface area, regardless of shape, color, or texture (13). Several other methods of measuring leaf area have been devised but none are adequate for the measurement of carrot leaves. Some of these methods are: (1) a planimeter, (2) measuring certain axes and applying a correction factor, (3) transferring or tracing on paper and weighing, and (4) removing known areas and weighing and calculating total area from the total leaf weight. These methods are often inaccurate and time consuming, and can be applied only when the leaves are not deeply incised.

The intensity of light which penetrated the weed cover and reached the crop plants was measured. This was done with an instrument which measured directly the percentage of available light reaching the level of the crop plants, and is described by Miller (12). This instrument provided an averaged reading of intensity while the photo cell moved through a distance of several feet. This eliminated the need for a great number of individual spot readings to compensate for sunny and shady areas.

RESULTS

As has been indicated, the effect of weed competition was studied on three crops; carrots, onions, and beets. Data for each of these crops are reported separately.

The effect of weed competition on carrots

Several measurements were made on the crop plants both early in the season at which time the competition was removed, and again in the fall after the plants had completed their productive growth free from further weed competition. Although the experiment on carrots was conducted in both 1952 and 1953 with only minor variations in procedure, the data which are reported were obtained from the 1953 experiments. Data from both seasons showed similar trends.

The effect of weed competition on carrots may be seen in Tables 1 and 2. The data show the degree of injury when expressed as the per cent reduction from the weed free control. The injury as measured in the spring at the time the weeds were removed and in the fall at maturity are presented in adjacent columns to enable the comparison of the two. It will be noted that the injury in all cases was greater when measured at the time the weeds were removed early in the season than it was at maturity in the fall. It is clearly evident that considerable recovery had occurred after the weeds were

removed. However, in only a few cases, where competition was very light, was recovery complete.

The initial injury in the spring was very severe, even when a 15 per cent weed stand competed for only 3½ weeks after emergence. In those cases where statistical significance was not obtained, definite trends were established which indicated that some injury had been inflicted. Data were not taken on root weights at the 3½ week period because the roots had not begun to enlarge.

Table 1. The effect of weed competition on yield and total plant weight of carrot plants. Measurements expressed as per cent reduction from the weed free controls.

Weed stand (per cent)	Duration of competition (weeks)	Pct. reduction in yield (fresh weight of roots)		Pct. reduction in total plant weight	
		Spring	Fall	Spring	Fall
15	3½	—	11.6	28.3	+5.4
30	3½	—	4.5	38.4	+9.6
50	3½	—	11.6	52.8*	+9.1
15	4½	73.6**	30.1**	49.8**	24.1
30	4½	81.2**	30.6**	64.3**	39.7**
50	4½	92.9**	44.5**	81.1**	41.1**
15	5½	77.7**	38.7**	56.6**	34.7**
30	5½	87.4**	47.4**	60.4**	28.5*
50	5½	90.9**	61.9**	65.2**	65.5**

*Significantly different from weed free check at the 5% level.
**Significantly different from weed free check at the 1% level.

Table 2. The effect of weed competition on root diameter and leaf area of carrot plants. Measurements are expressed as per cent reduction from the weed free controls.

Weed stand (per cent)	Duration of competition (weeks)	Pct. reduction in root diameter		Pct. reduction in leaf area	
		Spring	Fall	Spring	Fall
15	3½	12.6	3.5	8.4	3.0
30	3½	25.3**	0.9	9.1	+7.5
50	3½	30.1**	0.9	25.0	+5.7
15	4½	41.2**	10.7**	40.6*	9.4
30	4½	52.7**	10.0**	49.3**	12.5
50	4½	55.0**	17.8**	69.4**	28.7*
15	5½	50.1**	14.0**	66.0**	26.8*
30	5½	58.1**	23.9**	63.0**	33.7*
50	5½	62.2**	32.5**	73.8**	36.1*

*Significantly different from weed free check at the 5% level.
**Significantly different from weed free check at the 1% level.

When the weeds remained for periods longer than 3½ weeks highly significant reductions from the weed free control were obtained in most of the spring measurements. The greatest of these reductions occurred in the weight of carrot roots, which exceeded 90 per cent in some cases. This would seem to indicate that the underground portions of the plant were the first to be seriously injured by early season competition.

It may be seen from Tables 1 and 2 that in most of the measure-

ments the 15 per cent weed stand seriously injured the crop. In many cases, any further increase in weed stand produced reductions only slightly greater than those from a 15 per cent weed stand. This trend was more pronounced at the 5½ week period than at the earlier dates. In other words, nearly as much damage was eventually inflicted on the crop by a 15 per cent weed stand as by a much more dense stand.

It may also be seen that most of the injury, when indicated by the total plant weight and root weight, occurred by 4½ weeks after emergence. An additional week increased the degree of injury only slightly. The period from emergence to 4½ weeks after emergence appeared to be a critical stage in the competition of weeds.

The extent of the reductions in area of the carrot leaves is evident in Table 2. The degree of these reductions is noteworthy, as the photosynthetic capacity of a plant would be expected to be nearly directly proportional to its leaf area.

The fresh weight of weeds produced was recorded at each date of removal during the early part of the season. These weights are presented in Table 3. It appears that with increments of time and weed concentration a point was reached where the weight of weeds was independent of the weed stand. The weed weight tended to attain a constant or maximum at this point. This is significant from the standpoint that the injury to the crop also tended to level off at this point.

Table 3. Average fresh weight of weeds per plot when grown in competition with carrots

Weed stand (per cent)	Date of weed removal (time after emergence)		
	3½ weeks	4½ weeks	5½ weeks
	Lbs.	Lbs.	Lbs.
15	3.19	3.69	17.45
30	5.17	15.51	20.50
50	6.90	16.80	22.30
LSD (.05)	1.39	2.70	2.42
LSD (.01)	1.98	3.76	3.81

Determinations of the amount of light which was transmitted through the weed cover to the level of the top of the carrot plants were made in 1953. It was found that as early as 3½ weeks following emergence of the carrots, less than 50 per cent of the available light reached the crop plants. At the higher levels of competition only 15 per cent of the light was transmitted to the crop. These data are presented in Table 4. These severe reductions of light intensity provide some indication of the degree to which the photosynthetic capacity of the plants must have been impaired.

It may be seen from the table that at the 5½ week period particularly, the 15 per cent stand of weeds reduced the light intensity nearly as severely as the higher levels of weed population. This is very similar to a trend observed in the weight of weeds produced and indicates a close relationship of the two factors.

Table 4. Per cent of the total light intensity transmitted to the level of the carrot plants.

Weed stand (per cent)	Date when readings taken (time after emergence)		
	3½ weeks	4½ weeks	5½ weeks
	per cent	per cent	per cent
15	48.8	22.9	17.3
30	36.7	18.4	14.0
50	28.8	14.9	15.2

The effect of weed competition on onions

The experiment to determine the effects of weed competition on onions was conducted in essentially the same manner as the one on carrots already described. The same levels of weed stand were used; viz. 15, 30, and 50 per cent of the normal stands, and the weed competition was removed at 4, 5, and 6 weeks after the emergence of the onions.

Several growth meaurements were made on the onion plants during the early part of the season at the end of the competitive period. These included the number of plants, diameter at the base of the plants, weight of plants, and the number of leaves per plant. Similar plots which also received weed competition during the early part of the season only, were harvested at maturity in the fall. The number and weight of bulbs according to size were recorded at this time.

As indicated, the diameter of the basal portion of the leaves above the stem plate was measured while the seedlings were still very small. In many cases, it was obvious that bulbing had not been initiated, while in others, bulbing had already begun when some of the measurements were taken. To facilitate clarity of description therefore, the measurements of the diameter of the base of the plant, whether taken before or after bulb initiation, will be referred to as the diameter of the bulb.

Weed competition produced some very interesting effects on the development of the onion plant. In 1952, it was observed that when onions were subjected to intense weed competition, small bulbs were formed early, and these failed to reach normal size. This was also observed in the more extensive trials of 1953. In this season, some degree of bulbing was evident when the plants were under competition for 6 weeks, whereas there was no indication of bulbing in those plants which were free of competition for the same period.

The effect of early weed competition on onions in the spring at the time that the weeds were removed may be seen in Table 5.

The extent of the reductions in the weight of onions should be noted. These were extremely severe, particularly when the weeds remained in competition for 6 weeks. Because of considerable variation both between and within the replicates, the L. S. D. was exceptionally high. However, despite this variation the expected trend and a high degree of significance was obtained.

It is significant that while under the influence of competition, the

Table 5. The effect of weed competition on onion plants early in the season. Measurements are expressed as per cent reduction from the weed free controls. 1953.

Weed stand (per cent)	Duration of competition (weeks)	Pct. reduction of bulb diameter	Pct. reduction of fresh bulb weight
15	4	16.2	25.4
30	4	16.7	29.9
50	4	31.6	43.7*
15	5	33.6**	47.6**
30	5	45.5**	68.4**
50	5	47.0**	76.3**
15	6	50.2**	86.4**
30	6	59.4**	93.6**
50	6	62.6**	91.8**

*Significantly different from the weed free check at the 5% level.
**Significantly different from the weed free check at the 1% level.

number of leaves (including the cotyledon) per plant did not increase but remained nearly constant (Table 6). This may have been a result of the bulb formation which occurred during competition. This is consistent with the observations made by Heath and Holdsworth (7) who state that leaf production ceases when bulb formation begins.

The weed competition to which the onions were subjected early in the season greatly affected the size of the mature bulbs. The bulbs were graded into size classes, and the per cent of the total number

Table 6. The number of leaves per onion plant early in the season. 1953.

Weed stand (per cent)	Duration of competition (weeks after emergence)		
	4 weeks	5 weeks	6 weeks
Check (weed free)	3.24	5.14	6.35
15	3.11	4.19	3.29
30	3.03	3.74	3.54
50	2.90	3.41	3.24
LSD (.05)	N.S.	.35	.65
LSD (.01)	N.S.	.52	.91

which fell into each group is presented in Fig. 1. It may be seen that when the weeds competed for 4 weeks, the proportion of small bulbs increased only slightly. When competition remained for periods longer than this the proportion of small bulbs increased to greater than 90 per cent in some cases, with a corresponding decrease in large bulbs.

The effect of weed competition on red beets

The experiment to determine the effects of weed competition on red beets was conducted in 1953 in essentially the same manner as those described, except that only two replications were used. Statistical analysis was not performed on the data. It was hoped that this procedure would provide sufficient information to enable a comparison to be made with the other crops.

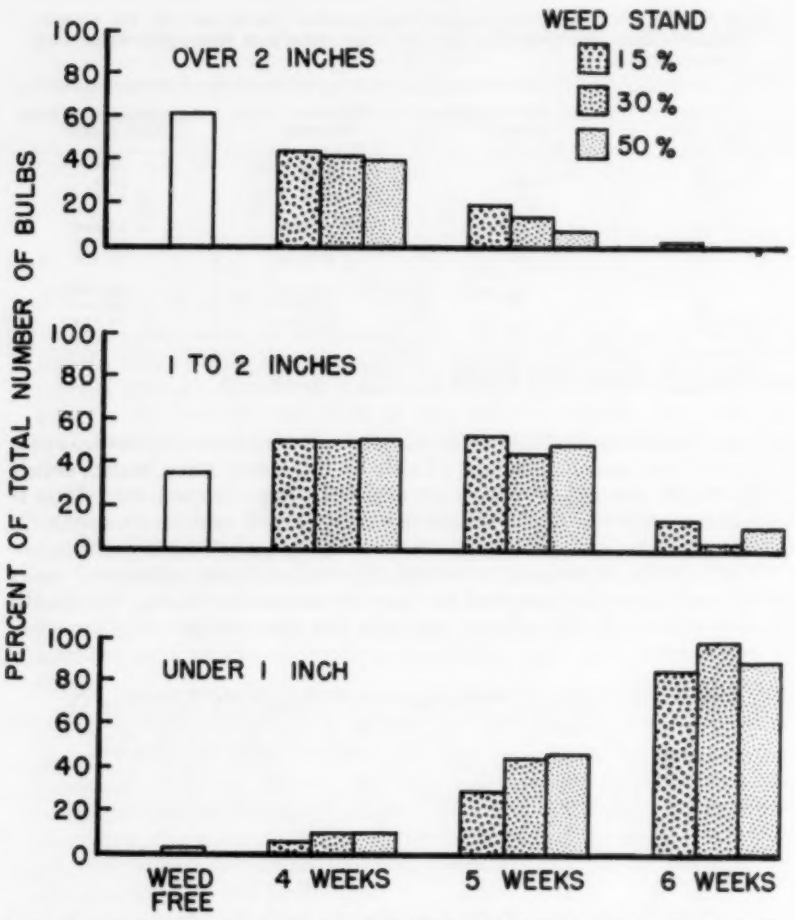

Figure 1. Per cent of the total number of onion bulbs which fell into the three size classes: over 2 inches, 1 to 2 inches, and under 1 inch in diameter when harvested at maturity.

Again, data were taken early in the season at the end of the competitive period, and in the fall after receiving competition only during the early part of the season.

When measured early in the season, the total fresh plant weight and the root diameter showed reductions from the weed free check of greater than 40 per cent, even when the weeds remained only 4 weeks after emergence. The fresh weight of roots was somewhat more severely affected by the competition. These data are presented in Table 7.

The degree of reduction in total plant weight and root weight of beets in the spring was very similar to that found in carrots when subjected to similar levels of weed competition. On the other hand

Table 7. The per cent reduction from the weed free check of the total weight of beet plants, and the weight and diameter of the roots. Measurements were taken early in the season at the time that the weeds were removed. 1953.

Weed stand (per cent)	Duration of competition (weeks)	Pct. reduction in total plant weight	Pct. reduction in root weight	Pct. reduction in root diameter
15	4	14.6	16.7	22.2
30	4	32.7	27.2	30.0
50	4	49.2	58.4	38.9
15	5	36.4	56.5	29.9
30	5	36.9	59.8	31.8
50	5	41.3	63.3	40.2
15	6	21.7	16.4	22.9
30	6	34.0	53.2	34.7
50	6	41.9	61.7	41.5

the reduction in the diameter of beet roots was not as severe as was the case with carrots.

No consistent differences were found in the stand or the total leaf area of the plants when measured at the time competition was removed early in the season.

The plots which received competition only during the early part of the season, but were weeded and left until fall showed only a slight amount of injury when compared to the controls which were free from weeds for the entire season.

It may be seen in Table 8 that the total weight of plants and the

Table 8. The per cent reduction from a weed free check of the total weight of beet plants, and the weight of roots. Measurements were taken in the fall after receiving competition only early in the season.

Weed stand (per cent)	Duration of competition (weeks)	Pct. reduction in total plant weight	Pct. reduction in root weight
15	4	14.1	18.6
30	4	+5.7	+27.9
50	4	+2.0	+11.8
15	5	2.9	2.4
30	5	14.8	11.8
50	5	13.0	6.4
15	6	3.5	+13.7
30	6	16.3	6.4
50	6	27.2	21.0

weight of roots in the fall were not reduced seriously from the weed free controls under most levels of weed competition. Considerable reduction occurred only when a 50 per cent weed stand competed with the crop for 6 weeks after emergence.

The total leaf area produced and the stand of beet plants at maturity in the fall after receiving weed competition during the early part of the season showed no appreciable differences from the weed free controls. Also, there were no differences in the number of unmarketable roots produced.

It may therefore be concluded from the existing data that by

maturity in the fall, the beet plants had made almost complete recovery from the injurious effects of weed competition early in the season.

DISCUSSION AND CONCLUSIONS

One of the primary goals of a weed control program—chemical or otherwise—is to obtain the greatest possible reduction in weed stand without injury to the crop. In order that weed control be profitable, the stand must be reduced to a point where further hand weeding and cultivation is reduced or eliminated. In the execution of such a program, it would be of great value to know how many weeds can remain in a crop without causing reductions in yield or quality. Likewise, it would be important to know how long they may remain in the crop and at what stage of development or season of the year competition is most critical. Attempts were made to answer some of these questions.

From these experiments, it is possible to compare the effects of similar levels of weed competition on the three crops, carrots, onions, and beets. Because of morphological differences between the crops, only general statements can be made. Onions were found to be more easily injured by early season weed competition than the other crops studied. This is probably a result of their upright narrow leaves, and their limited photosynthetic capacity during the early stages of growth. Beets on the other hand appeared to have the greatest tolerance to weed competition. This may be accounted for by the early production of several large leaves, and the consequent shading of the weeds immediately surrounding them. Carrots with more delicate, finely cut leaves which develop slowly were intermediate in their tolerance to weed competition.

The three crops also differed in their ability to recover after the competition was removed. Beets showed nearly complete recovery by fall after being in competition during the early part of the season. Recovery of the carrot plants was complete only when the length of the early competition did not exceed 3½ weeks. Onions on the other hand showed practically no recovery after the weeds were removed. It will be remembered that no new leaves were produced by the onions during the latter part of the competitive period. This loss of ability for the production of new leaves has been shown to be a natural consequence of bulb initiation (7). If only a small number of early leaves had emerged when bulbing was initiated, small bulbs would be expected to result.

The reason for the abnormally early bulb formation in onions which were subjected to weed competition cannot be determined from the data. The primary stimulus for bulb formation according to Heath and Holdsworth (7) is the exposure to long days. They indicate also that there is an interaction between photoperiod and temperature such that at lower temperature, longer days are required for bulb development to begin and vice versa. Weed competition in this experiment would not be expected to produce conditions of either longer days or higher temperatures which would induce bulb initiation.

Pavlychenko and Harrington (15) determined that one of the first indications of injury from competition appeared beneath the soil surface. This was also true in the present experiments where injury to the underground portions appeared to be generally much greater and occur sooner than to the tops of the plants.

It must be emphasized that all of these reductions occurred when only a portion of the total weed stand competed with the crop. In fact, in many cases, competition offered by a 15 per cent weed stand —three weeds per square foot—for only 3½ weeks, resulted in adverse effects on the crops. It appears that when considering injury to the crops by weed competition, weed concentration is much less important than had been expected. It has been shown that in time, a relatively sparse weed stand will cause as much shading and produce as much weedy material as will a much heavier stand. However, it must be emphasized that during very early weed competition, when weeds normally should be removed, this does not necessarily hold true. These results are in agreement with the work of Mann and Barnes (10) who found that on a given volume of soil, the ultimate weight of plant material produced reached a constant or maximum level regardless of the number of plants.

All of the factors which together constitute weed competition to crops, such as the concentration of weeds, degree of shading, etc. have very complex inter-relationships. The relationship of those factors to the total injury becomes difficult to define because any single measurement of growth which may be taken does not necessarily provide a good indication of total injury.

The degree of shading and the weight of weeds produced were quite closely correlated. Maximum shading however, occurred before maximum weed weight was obtained. On the other hand the degree of shading increased in proportion to the concentration of weeds only during the first few weeks of competition. When the competition remained for periods longer than 3½ weeks the degree of shading tended to reach a maximum, independent of the weed concentration.

The actual portion of the total injury which was caused by the reduced light intensity could not be determined from this experiment. There are good indications that this factor played a very important role. There is for example, a very close relationship between the reduction in the amount of light reaching the crop and such growth measurements as root diameter, weight, etc. taken early in the season. Thomas and Hill (22) found that the photosynthetic rate in alfalfa was very closely correlated with light intensity when measured in the field. Other experimenters have shown that reduced light intensity may affect the leaf area (5), leaf thickness (19, 20), root-top ratios (1, 2, 14) stem thickness, (16) and the rate of nutrient uptake (17).

Another factor which undoubtedly limited the photosynthetic capacity of the crop plants was the reduced leaf area. These reductions were as great as 75 per cent in some cases. It is not clear

whether these were caused by the reduced light intensity or by some other factor.

Little is known of the role of light quality and light duration (photoperiod) in plant competition, and no attempts were made to investigate this aspect of the problem.

It should be noted that the period from emergence to 4½ weeks was a critical period in competition. A further increase in the length of the period of competition produced less than a proportionate increase in the total injury. This serves to emphasize the importance of timely weed control. In connection with this finding, it must be remembered that as few as three weeds per square foot remaining for this period resulted in serious losses.

SUMMARY

On the basis of experiments conducted on an organic soil at Madison, Wisconsin, it was found that weed competition during the early part of the season caused many adverse effects on vegetable crops. Several controlled levels of weed population were used, and it was concluded that concentrations as low as 15 per cent of the normal stand of weeds were capable of inflicting serious injury to the crop plants. In fact, these sparse weed stands caused almost as much damage as much denser stands.

The period from emergence to four weeks was shown to be a critical stage in the competition of weeds with row crops.

The yield of carrot plants was greatly reduced as a result of weed competition. These reductions varied from 30 to 60 per cent depending upon the severity of the competition. The total plant weight, diameter of roots, and leaf area, were also considerably reduced by weed competition. These reductions were evident when measured at the time that the weeds were removed early in the season, and also at harvest in the fall when the crop had received competition from weeds for only the first 3 to 5 weeks of the growing season. The injury was much more severe when measured early in the season than it was in the fall, indicating that the carrot plants had made considerable recovery after the weeds were removed.

In less extensive trials it was found that onions and beets were similarly injured by weed competition. The beet plants were found to have greater ability to recover after the weeds were removed early in the season.

Onions were very severely injured by weed competition and showed yield reductions of greater than 90 per cent at the higher levels of weed competition. It was also observed that bulbing was induced pre-maturely under competition from weeds in the early part of the growing season. These bulbs increased little in size after the weeds were removed and at harvest time most were under one inch in diameter.

Weed competition was found to shade the crop plants to the extent of reducing the light intensity at the crop level by as much as 85 per cent in some instances. It is suggested that this severe reduction

in light intensity was responsible for much of the injury which was suffered by the crop plants.

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Some Effects of 2,4–Dichlorophenoxyacetic Acid upon Azotobacter as Measured by Respiration Inhibition

LYMAN A. MAGEE and ARTHUR R. COLMER[1]

DURING recent years the increasing use of herbicides for the control of weeds in croplands has stimulated interest in the effect of these chemicals upon the soil microflora. In 1953 Hoover and Colmer (4) showed that the application of 2,4–D to Sharkey sugarcane soil in concentrations comparable to that used in the field had little effect upon the bacteria, actinomycetes, and fungi of this soil. Colmer (1), using the Winogradsky soil plaque technique which can serve to gauge the effect of herbicides upon the nitrogen-fixing genus *Azotobacter* in their natural habitat, found that field application rates were not harmful to *A. chroococcum,* and it was only when prohibitive rates of application of 2,4–D (400–600 ppm) were used that growth was markedly affected.

Magee and Colmer (5) by means of a manometric procedure studied the effects of several herbicides in inhibiting the respiration of three members of the genus *Azotobacter,* and noted a difference in the activity of the agents upon the respiration of the species.

This report is a part of a continuing investigation on aspects of the action of herbicides on soil microflora. It reports on a correlation of the effect of the herbicide with the respiration of *Azotobacter* of different ages, on a comparison of the effects of the herbicide upon resting cells with the effects upon actively respiring cells, and on a comparison of the viability of the cells with their respiration after exposure to the herbicide for varying periods of time.

EXPERIMENTAL METHODS

The organisms used in these studies were stock cultures of *A. agile* and *A. vinelandii* strain Original, and a culture of *A. chroococcum* freshly isolated from Mhoon type sugarcane soil. The cells were grown at 30° C. on agar bottle slants of a nitrogen-free mineral salts medium (Fred and Waksman, 3). In each case the cells were harvested by washing from the medium with neutral phosphate buffer and the suspension was adjusted to a standard turbidity with the Klett-Summerson colorimeter. The buffer solution used throughout these studies for the suspension of the cells consisted of 50 ml of 0.2 *M* KH_2PO_4 mixed with 29.63 ml of 0.2 *M* NaOH and had a pH of 7.0.

The oxygen absorption was determined in the Warburg respirometer, using 1 ml each of the cell suspension and the medium, 0.1 ml of 20 per cent KOH in the center well, and in the sidearm, 0.5 ml of the triethanolamine salt of 2,4–D to give the desired final concentration in the main compartment of the flask after tipping. An endogenous control consisting of 1 ml of cells and 1 ml of phosphate

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buffer, with one-half ml of buffer being added after one hour, was included with each test made.

Each experiment was repeated several times. The results presented below were selected as being most representative of their respective series.

Experiment A: The cells used in these tests were harvested when either 24- or 48-hours old. For the test the cells were placed in the Warburg vessels with the medium and allowed to incubate for 1 hour, after which time the test herbicide solutions were tipped into the main compartments from the sidearms. Incubation was continued for 2 hours, with manometer readings being taken at 15 minute intervals.

Experiment B: This type of test consisted of three parts: Flask 1 contained cells and medium, and neutral phosphate buffer solution was added after 1 hour of incubation. Flask 2 contained cells, medium, and herbicide. Nothing was added after 1 hour of incubation. Flask 3 contained cells and herbicide, and the medium was added after 1 hour of incubation.

Experiment C: Cells of *A. agile* 24-hours old were used for this experiment. The cell suspension was placed in the Warburg flasks with medium and buffer, and at the end of a half hour a loopful of the mixture was removed from the flask and used to streak an agar slant. This served as the control. The herbicide was tipped in from the sidearm after 1 hour of incubation, and immediately another slant was streaked. Further tests for viability of the cells were made at the end of 1 and 2 hours.

RESULTS AND DISCUSSION

Relative susceptibility of cultures of different ages to the inhibitory action of 2,4–D. Table 1 shows that with *A. agile* and the lower levels of 2,4–D (2,000–5,000 ppm) there was little difference in the inhibition of oxygen uptake whether 24-hour or 48-hour old cells were used, but at the 10,000 ppm level the younger cells were much more resistant to the chemical. At the 15,000 ppm concentration of 2,4–D a graph made of the oxygen uptake versus time shows a hori-

Table 1. Influence of 2,4-D upon oxygen uptake by cells of *Azotobacter* of different ages.

Age of cells	Total oxygen uptake in µl by end of 3 hours						
	Endogenous respiration	Active respiration					
		Ppm 2,4-D					
		0	2,000	5,000	7,000	10,000	15,000
24 hr. *A. agile*	273	1679	1545	1318	——	1251	426
48 hr. *A. agile*	11	1663	1400	1243	——	430	341
24 hr. *A. vinelandii*	146	1750	1558	1513	1538	675	560
48 hr. *A. vinelandii*	18	1393	1487	1267	875	415	393
24 hr. *A. chroococcum*	1092	1983	1638	1374	972	738	283
48 hr. *A. chroococcum*	18	238	71	49	55	40	4

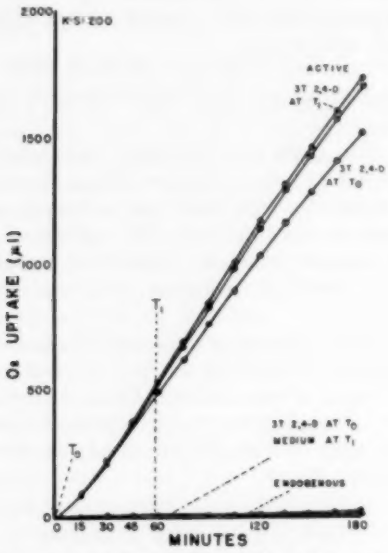

Figure 1. Comparison of the effects of adding 2,4–D to actively respiring cells and to resting cells of *A. agile*.

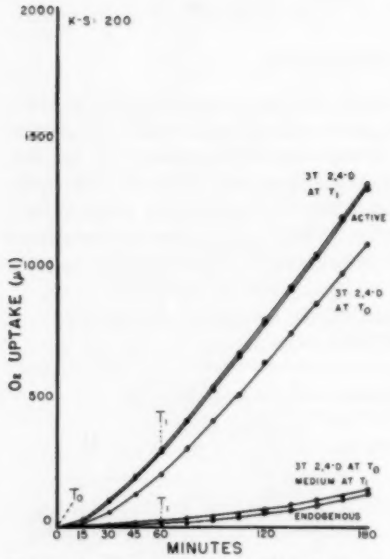

Figure 2. Comparison of the effects of adding 2,4–D to actively respiring cells and to resting cells of *A. vinelandii*.

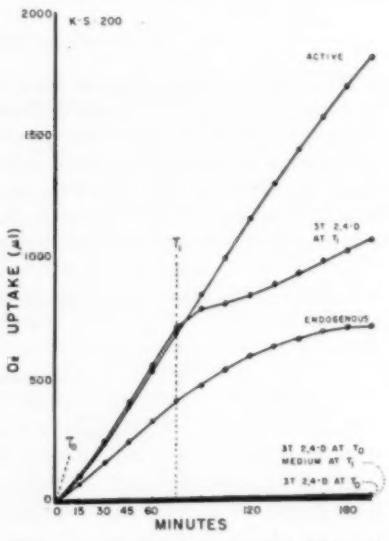

Figure 3. Comparison of the effects of adding 2,4–D to actively respiring cells and to resting cells of *A. chroococcum*.

zontal line, indicating that at this level the agent stopped respiration of cells irrespective of the age of the cells.

With *A. vinelandii* the results were similar to that of *A. agile* at the lower levels; however, since 10,000 ppm of 2,4–D had a rather marked effect on the respiration of *A. vinelandii* at any age of the cells, 7,000 ppm of the herbicide was used to demonstrate the response of the two ages at an intermediate level. At this concentration there was a more deleterious action upon the older cells.

A. chroococcum was shown to be more susceptible to the harmful action of the herbicide than were the other two organisms, and showed such a rapid decline in respiratory activity when harvested at ages greater than 24 hours that the effect of the herbicides on the older cells could not be accurately gauged. It is a point of interest to note that *A. chroococcum* always showed an endogenous respiration far greater than that of either of the other two organisms.

Relative susceptibility of actively respiring cells and resting cells to the inhibitory action of 2,4–D. Figures 1, 2, and 3 show that cells actively respiring in a suitable menstruum are more resistant to the harmful action of 2,4–D than when they are exposed to the 2,4–D under conditions which do not permit active respiration. In the figures the abbreviation "3T 2, 4–D" has been used to represent 3,000 ppm 2,4–D.

When 3,000 ppm of the herbicide were added to *A. agile* cells after 1 hour of active respiration there was little change in the oxygen uptake of these cells as compared to the active control which had no 2,4–D. When the same concentration of the herbicide was added to the cells at the beginning of the experiment so that they were subjected to its action as they responded to the presence of the substrate, there was but a slight inhibition in their oxygen uptake. However, when the cells were exposed to an identical concentration of 2,4–D for an hour before the nutrient medium was added, they did not recover and show any oxygen uptake in the following two hours. Indeed, the graph indicates their response to be similar to the endogenous control which had neither 2,4–D nor nutrient medium.

Similar results were secured with cells of *A. vinelandii* except that when the 2,4–D was added at the beginning of the test period with the nutrient medium, there was more inhibitory action than when the cells were allowed to respire actively for an hour before being subjected to the herbicide.

A. chroococcum showed a response different from that of the other two species in keeping with its greater sensitivity to the agent. These cells showed a marked inhibition in oxygen uptake when 3,000 ppm of the herbicide was added after 1 hour of active respiration; too, those cells exposed to the herbicide at the beginning of the test periods had their respiration completely inhibited, regardless of the presence of the nutrient medium. Figure 3 indicates also that even though this species had a high endogenous respiration originally, the presence of 2,4–D prevented these cells from becoming active when the medium was subsequently added.

Relation of viability of cells to their respiratory response in presence of 2,4–D. Figure 4 shows the growth of cells of *A. agile* following subculture from Warburg flasks subject to a typical experiment on inhibition of oxygen uptake.

A comparison of the amount of growth in the second tube of each test, made immediately after tipping in the herbicide, with the third and fourth tubes, made at one hour intervals afterwards, shows that there was a marked reduction in the number of viable organisms in the 10,000 ppm and 15,000 ppm concentrations, but

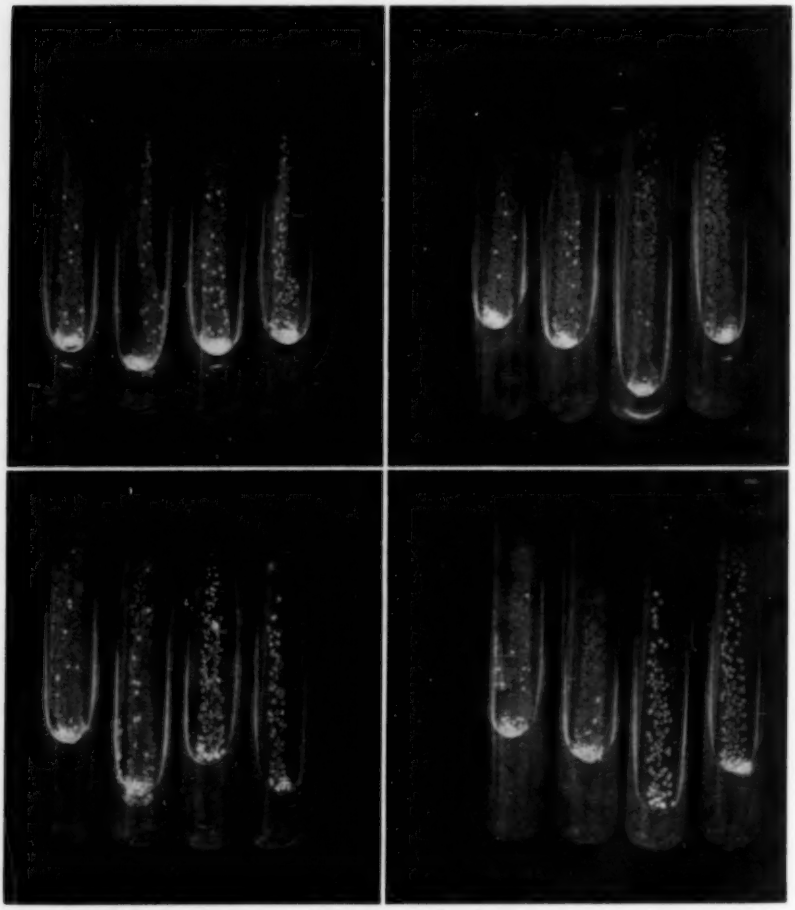

Figure 4. Slants of agar streaked with *A. agile* from Warburg flasks containing various concentrations of 2,4–D. The first tube in each series was streaked after one-half hour of incubation in the Warburg bath. The second tube was streaked one-half hour later, immediately after the addition of the 2,4–D. The third and fourth tubes were streaked at one-hour intervals after the addition of the 2,4–D.

Upper left: Control, no 2,4–D
Upper right: 7,000 ppm 2,4–D
Lower left: 10,000 ppm 2,4–D
Lower right: 15,000 ppm 2,4–D

it is significant that viable organisms could still be secured from a flask which had shown no oxygen uptake for the 2 hours following the tipping of the herbicide into the cell suspension. This is of interest in the light of the findings of Ely (2) who tested for viability of *Escherichia coli* after its exposure to different germicides in respiratory experiments. He noted that although respiration may be inhibited almost completely, positive subcultures still result and that when the oxygen uptake is reduced to zero the suspension contains only dead organisms.

The resistance of *A. agile* to the 15,000 ppm of the herbicide here is of interest in relation to the findings of Colmer (1) that although 5,000 ppm prevented the growth of *A. agile* in the N-free mannitol medium, the cells could be adapted to grow in a medium containing that concentration.

It is recognized that the findings made here with pure cultures of the *Azotobacter* do not necessarily reflect their response to the same agent when they are in the soil. It is highly probable, however, that the presently used rates of 1 and 2 ppm in the sugarcane fields are not harmful to these organisms irrespective of the many facets of their respiration in such an environment.

SUMMARY

1. Pure cultures of *A. agile*, *A vinelandii*, and *A. chroococcum* were harvested at 24 and 48 hours, and the effects of various concentrations of the triethanolamine salt of 2,4–dichlorophenoxyacetic acid on the respiration of the cells were measured manometrically. It was found that the younger cells of the organisms were more resistant to the harmful effects of the agent than were the older cells.
2. Cells which had been actively respiring in a suitable menstruum for 1 hour were more resistant to the harmful effects of 3,000 ppm of 2,4–D than were those cells which were in the suitable menstruum but were subjected to 3,000 ppm before active respiration began.
3. Resting cells exposed to 3,000 ppm of 2,4–D did not initiate active respiration when treated later with a suitable medium.
4. Cells of *A. agile* were found to retain a high degree of viability after two hours of exposure to 15,000 ppm of 2,4–D, although respiration was completely inhibited by as little as 10,000 ppm of 2,4–D.

ACKNOWLEDGMENT

The authors wish to express their appreciation to the Dow Chemical Company for support of this investigation.

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Factors Affecting the Herbicidal Action of Aqueous Sprays of Salts of 4,6–Dinitro-ortho-secondary Butyl Phenol[1]

WILLIAM F. MEGGITT, R. J. ALDRICH, and W. C. SHAW[2]

THE herbicidal properties of the sodium salt of 3,5–dinitro-ortho-cresol were recognized in the early 1930's. The dinitrophenols and dinitrocresols have since found wide use in controlling weeds in corn, peas, beans, potatoes, cotton, grains, forage legumes, and many other field and horticultural crops. The 4,6–dinitro-ortho-secondary butyl phenol (hereafter referred to as DNBP) and its salts are the most widely used compounds of this group in the United States.

Much of the work with the various formulations of DNBP has shown a variety of results with respect to their herbicidal activity. There is a range of reports of field observations from perfect weed control to complete failure and from no injury to complete kill of crop plants.

Environmental conditions are known to have an important effect on the results obtained with DNBP when it is applied as a pre- or post-emergence aqueous spray. Temperature before and after treatment may be an important factor in determining the degree of crop injury or weed control obtained with DNBP.

Little experimental work has been conducted to determine exactly how environmental conditions before, during, and after treatment with DNBP affect its herbicidal activity.

The following investigations under closely controlled conditions were conducted to help explain some of the variable results obtained with DNBP.

REVIEW OF LITERATURE

Many reports in the literature show highly satisfactory results with DNBP in spite of rather adverse weather conditions. Satisfactory control of chickweed in alfalfa and strawberries has been reported (3, 5). Several investigators report poor weed control when low temperatures prevailed after treatment (4, 15, 16). There are numerous reports of excessive crop injury when high temperatures occurred following treatment (1, 6, 7, 8, 12).

Taylor (15, 16), in a residual pre-emergence study, found better weed control when mean temperatures before treatment were below 70° F than when they were above 70° F. He also reported more

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effective weed control when temperatures were below 70° F after treatment.

Mitchell and Phillips (9) and Rahn and Hitz (11) found less injury when the temperature was below 65° F prior to treatment with DNBP. They attributed this to a "hardening" of the foliage by low temperatures. Other investigators also have felt that temperature, light intensity, and humidity prior to treatment affect the results obtained with DNBP (2, 13).

EXPERIMENTAL METHODS AND RESULTS

The experiments were conducted in the greenhouse and controlled environment growth chambers located at the United States Department of Agriculture Plant Industry Station at Beltsville, Maryland (10). The plants produced in these chambers were very satisfactory for experiments of this type.

Hawkeye soybeans were used as test plants for all of the experiments. Four soybeans were seeded in one-quart containers that had been thoroughly cleaned. After emergence the soybeans were thinned, leaving the two most uniform plants in each container. All plants were watered by means of sub-irrigation.

Aqueous sprays of DNBP were applied to soybeans when the first trifoliolate leaf had opened but not expanded. This normally occurred about 2 weeks after planting. Spraying was done on a moving table with the spray nozzle mounted overhead calibrated to deliver 40 gallons of solution per acre (14). The ammonium salt, triethanolamine salt, and alkanolamine salt, which is a mixture of the ethanol and isopropanol series, were used as indicated for each experiment.

Sprays were applied at ½, 1 and 2 pounds of DNBP equivalent per acre in most tests. Since there was no interaction of rate with the other variables, only the average of these rates is presented.

In all of the experiments height of plants, height of plants from the cotyledonary leaves to the terminal bud, fresh weight of the above-ground parts of plants, dry weight of the above-ground parts of plants, and an injury rating were used to measure the effect of DNBP on the test plants.

The injury rating was based on a scale of zero to 10, zero representing no injury and 10 signifying dead plants. Injury was based on the degree of burning and necrosis of the leaves, the loss of turgor in leaves and stems, stunting, and any other deviation from the apparently normal check plants. The injury ratings were made independently by four qualified persons.

All criteria used in measuring the activity of DNBP showed similar relative behavior in the studies. Only the injury ratings are included in this manuscript since they most clearly present the effects of the treatments on the test plants.

The measurements were taken at a time when it appeared the chemical had exerted its major effect. It was assumed that when any regrowth was noted on treated plants, the chemical had exerted most of its effectiveness. This occurred 4 or 5 days after treatment.

Effect of temperature after treatment

Soybeans in the first trifoliolate leaf stage were taken from the greenhouse and sprayed with the three salts of DNBP at ½, 1 and 2 pounds acid equivalent per acre. After treatment the plants were transferred to the growth chamber where they were exposed to temperatures of 50, 60, 70, 80, 90, and 96° F for 4 days.

The experimental design was a completely randomized block with six replications. Each temperature was considered a separate experiment because each was established in a separate growth room, and replications in one room bore no direct relationship to replications in another room.

A separate analysis of variance was carried out for each temperature. A combined analysis was then used to compare temperatures and all interactions involving temperatures.

The effect of temperature on the activity of DNBP salts is indicated in Table 1. The average activity of the three salts of DNBP increased as the temperature increased from 60° to 96° F. This is probably explained by the effect of temperature on a chemical reaction resulting in increased penetration of DNBP as well as increased activity after it has entered.

The ammonium salt resulted in a severe injury rating on soybeans at 50° F. The amine salts showed little activity until the temperature was 80° F. Above 80° F the activity increased as temperature increased.

Effect of light before and after treatment

Soybean plants were grown in the greenhouse until the first trifoliolate leaf had opened but not expanded.

In a preliminary experiment one group of plants was subjected to 16 hours of darkness to deplete the carbohydrates, and another group was subjected to 16 hours of light. After this exposure to light and darkness the plants were sprayed with the three salts of DNBP at 1 pound DNBP equivalent per acre. One-half of each light- and dark-group was then placed under 16 hours of darkness,

Table 1. The effect of temperature following treatment on injury to soybeans by three DNBP salts as indicated by injury ratings.

Formulation of DNBP	Injury rating[1]						
	50°	60°	70°	80°	90°	96°	Mean[2]
Ammonium salt	7.8[3]	6.8	7.8	8.1	8.3	9.2	8.0
Triethanolamine salt	3.0	2.8	3.9	6.0	7.0	7.8	5.1
Alkanolamine salt	1.8	1.9	2.2	5.4	6.8	6.9	4.1
Mean all formulations[4]	4.2	3.8	4.6	6.5	7.4	8.0	

[1]0 = no injury; 10 = dead.
[2]LSD formulation means .05 = .18; .01 = .23.
[3]LSD temperature × formulation .05 = .41; .01 = .54.
[4]LSD temperature means .05 = .23; .01 = .31.

and the remaining half under 16 hours of light, giving combinations of dark-dark, dark-light, light-light, and light-dark. Plants were kept at 80° F during exposure before and after treatment. After the

16-hour exposure following treatment, all plants were placed on a 12-hour light and dark schedule. Measurements and harvests were taken after plants had been on the 12-hour schedule for 4 days.

In a later experiment the plants were exposed to light and dark for varying periods of time. They were treated with the ammonium and alkanolamine salts of DNBP at 1 pound DNBP equivalent per acre. Following treatment part of the plants were placed in light and part in dark at 80° F. Plants were removed from their respective light and dark conditions at intervals of 2, 4, 6, 8, 10, 12, and 16 hours and placed under the opposite conditions for 12 hours. Then they were placed on a 12-hour light and dark schedule for 4 days.

The experimental design for both of the preceding experiments was a split plot. In the first experiment there were five replications, and in the second there were four. The light and dark condition in each experiment was the whole plot.

The amount of injury was dependent on the light condition after treatment. All formulations of DNBP produced much more injury on plants that were in the dark 16 hours following treatment than on those in the light for the same period. This difference was highly significant irrespective of the light condition before treatment. There was no difference in injury to plants that were placed in the dark and those that were placed in the light before treatment.

In the preliminary experiment the ammonium salt produced the most injury, the triethanolamine was intermediate, and the alkanolamine produced the least injury.

The data for the time interval exposures to light and dark conditions are found in Table 2. The ratings are the average of both formulations since they showed similar relative effects although the ammonium DNBP was again more injurious than the alkanolamine.

The differences among the various exposures were highly significant. Twelve and 16 hours in the light after treatment significantly reduced the injury to the soybeans over 12 and 16 hours in the dark. Sixteen hours in the light gave significantly less injury than any other exposure to light. There was no difference among exposures to light of less than 16 hours.

The amount of injury tended to be directly related to the length of the dark period immediately following treatment. Plants placed for 2 hours in dark and then 12 hours in light were injured less than all other exposures to dark. Sixteen hours in the dark produced significantly more injury to plants than any other.

It would seem that light affected the plant or the activity of the DNBP in such a way that less injury was produced under light conditions following treatment. This exposure had to be at least 12 hours, and the effect was much more evident after 16 hours exposure. The long light period also reduced injury on plants placed in short exposures of darkness before being placed in the light. It would appear that the effect of the light was manifested before the DNBP had exerted much of its total effect if the dark period was short following treatment.

Table 2. The effect of light conditions after treatment on injury to soybeans by DNBP as indicated by injury ratings.

Hours exposed	Injury rating[1]	
	Dark[2]	Light[2]
2	6.4	7.4
4	6.9	7.1
6	7.3	7.5
8	7.4	7.4
10	6.7	7.5
12	7.9	7.2
16	8.8	5.0

[1]0 = no injury; 10 = dead.
[2]LSD .05 = .57; .01 = .75.

Effect of temperature prior to treatment

Soybeans were germinated at 85° F in the greenhouse. At emergence they were transferred to the growth chambers and grown at 60°, 70°, 80°, and 90° F until they reached the first trifoliolate leaf stage. This required about 6 days at 80° and 90° F. and 7 to 8 days at 60° and 70° F. The plants were sprayed with the three salts of DNBP at ½, 1, and 2 pounds DNBP equivalent per acre. Plants were then kept at 80° F until data were recorded 4 days after treatment. The experimental design was a completely randomized block with five replications. Each temperature was considered a separate experiment.

The effect of the three salts of DNBP on soybeans grown from emergence to the first trifoliolate leaf stage at temperatures of 60°, 70°, 80° and 90° F is shown in Table 3.

The salts of DNBP produced significantly more injury on plants grown at 70° and 80° F. than on those grown at 60° and 90° F. There was no difference in injury ratings between plants grown at 60° and 90° or between those grown at 70° and 80° F. Plants that were grown at 80° and 90° appeared similar as to type of growth at time of treatment. They were elongated and had small leaves as a result of limited light in the chambers. Plants grown at 60° and 70° were shorter and had larger leaves. Stems were much thicker than on those plants grown at 80° and 90° F.

In these tests there was a highly significant difference in injury

Table 3. The effect of growing temperature prior to treatment on injury to soybeans by three salts of DNBP as indicated by injury ratings.

Formulation of DNBP	Injury rating[1]				
	60°	70°	80°	90°	Mean all temperatures[2]
Ammonium salt	6.7	9.3	9.9	6.8	8.2
Triethanolamine salt	2.8	5.9	5.9	2.9	4.4
Alkanolamine salt	2.9	5.8	6.1	2.6	4.4
Mean all formulations[3]	4.1	7.0	7.3	4.1	

[1]0 = no injury; 10 = dead.
[2]LSD temperature means .05 = .33; .01 = .44.
[3]LSD formulation means .05 = .27; .01 = .36.

between the ammonium salt and the amine salts. The ammonium produced much more injury than the amine on the test plants at all temperatures. There appeared to be no difference between the triethanolamine and the alkanolamine salt.

Time of exposure to different temperatures

Plants were grown in the greenhouse until approximately 1, 2, and 3 days before the first trifoliolate leaves opened. At these intervals they were transferred to the growth chambers and exposed to 70°, 80°, and 90° F for periods of 20, 36, and 60 hours before treatment. All plants, after the appropriate time of exposure, were treated with the ammonium and alkanolamine salts of DNBP at 1 pound DNBP equivalent per acre. Plants were kept at 80° F until data were recorded 4 days after treatment. The experimental design was a completely randomized block with five replications. Each temperature was considered a separate experiment.

The effect of exposure periods at different temperatures is shown in Table 4. Plants which were exposed for 20, 36 and 60 hours to 70°, 80°, and 90° F showed the same reaction to DNBP as plants grown at these temperatures from emergence to the first trifoliolate leaf. Plants which were exposed to 90° F for either 20, 36, or 60 hours were injured less by DNBP than those exposed to 70° and 80° F.

Table 4. The effect of short exposure to different temperatures before treatment on injury to soybeans by two salts of DNBP applied at 1 pound per acre as indicated by injury ratings.

Hours exposed to temperatures	Formulation of DNBP	Injury rating[1]			
		70°	80°	90°	Mean
20	Ammonium	9.2	9.2	5.9	8.1
	Alkanolamine	4.9	4.9	3.0	4.3
	Mean	7.0	7.0	4.4	
36	Ammonium	9.4	8.6	6.9	8.3
	Alkanolamine	3.9	2.9	1.3	2.7
	Mean	6.6	4.8	4.1	
60	Ammonium	10.0	9.8	8.2	9.3
	Alkanolamine	2.8	4.9	2.5	3.4
	Mean	6.4	7.4	5.4	
Mean all formulations and exposures		6.7	6.7	4.6	

[1] 0 = no injury; 10 = dead.

Light intensity and temperature

Soybeans were germinated in the greenhouse at 85° F. At emergence the plants were placed in three different greenhouse sections which were maintained at 70°, 80° and 90° F, respectively, under conditions of normal and one-half normal light. The condition of one-half normal light was accomplished by shading with two layers of cheese cloth. When plants reached the first trifoliolate leaf stage they were sprayed with the ammonium and alkanolamine salts of

DNBP at ½, 1, and 2 pounds DNBP equivalent per acre. After treatment plants were placed in one greenhouse at 80° F under normal light conditions. Data were recorded 5 days after treatment. The experimental design was a split plot with eight replications. Each temperature was considered a separate experiment. The level of light intensity was the whole plot factor.

The effect of light intensity and temperature on injury is shown in Table 5. Regardless of light intensity DNBP produced less injury on plants grown from emergence to the first trifoliolate leaf at 90° as compared to 70° and 80° F. Under conditions of normal light the injury ratings show no difference between 70° and 80° plants.

Plants grown under the reduced light intensity were injured more by both formulations of DNBP than those grown under normal light intensity irrespective of temperature. Plants grown under low light were elongated and quite spindly compared with those grown under normal light. This was especially true at the higher temperatures of 80° and 90° F.

Table 5. The effect of growing temperatures and light intensities prior to treatment on injury to soybeans by two salts of DNBP as indicated by injury ratings.

Formulation of DNBP	Injury rating[1]					
	Normal light			One-half normal light		
	70°	80°	90°	70°	80°	90°
Ammonium	9.4	9.2	8.2	9.6	9.4	9.4
Alkanolamine	6.0	5.1	4.5	6.3	6.5	4.9
Mean all temperatures and formulations	7.1			7.7		

[1] 0 = no injury; 10 = dead.

Again, as in all previous experiments, the ammonium salt produced more injury than the alkanolamine salt.

SUMMARY

A study was made of several factors which affect the results obtained from the application of dinitro-ortho-secondary butyl phenol as a herbicide. The investigations were conducted in the greenhouse and controlled environment chambers at the United States Department of Agriculture, Plant Industry Station, Beltsville, Maryland.

The effects of temperature and light, prior to, during, and following treatment with DNBP salts were studied. The temperatures ranged from 50° to 96° F.

The criteria used for determining the injury produced by aqueous sprays of DNBP were fresh weight, dry weight, total height, height from cotyledonary leaves to terminal bud and injury ratings of soybean test plants.

The results of these investigations follow:

1. The activity of the DNBP increased as temperature *after* treatment increased from 60° to 96° F.

2. The activity of DNBP was less under growing temperatures of 60° and 90° *prior* to treatment than with temperatures of 70° and 80° F.

3. Light *following* treatment reduced the apparent activity of DNBP whereas light conditions *prior* to treatment had no effect.

4. Plants grown under low light intensities were injured more than those grown under higher light intensities.

5. The ammonium salt of DNBP was much more phytotoxic than the amine salts. The triethanolamine salt was slightly more active than the alkanolamine salt.

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Some Factors That Influence the Effectiveness of 2,4,5–Trichlorophenoxyacetic Acid in Killing Mesquite

C. E. Fisher, C. H. Meadors, and Richard Behrens[1]

Since the discovery of the growth substance activity of the phenoxy acids by Zimmerman and Hitchcock (14) in 1942 and the announcement of 2,4–dichlorophenoxyacetic acid (2,4–D) and 2,4,5–trichlorophenoxyacetic acid (2,4,5–T) as herbicides by Hamner and Tukey (9) in 1944, a new era in chemical weed control has developed. In 1949 workers at the Texas Agricultural Experiment Station at Spur, and the Weed Investigations Section of the U.S.D.A. (6) reported that aerial application of 2,4,5–T offered much promise of effectively and economically controlling mesquite on rangeland. Since that time, approximately 1,500,000 acres of mesquite infested grassland have been treated with this compound by aerial application. Though widespread use of 2,4,5–T has been made, the factors that influence its effectiveness in killing mesquite are not well understood. This paper attempts to summarize the information that is available on some of these factors.

Mesquite, *Prosopis juliflora,* is a woody sprouting shrub that occurs on approximately 70 million acres of grassland in the Southwest. It grows in hot, dry climates and exhibits many growth forms ranging from dense thickets of small shrubs to large trees. All growth forms of mesquite have a well defined zone of dormant buds below ground level. This bud zone must be destroyed or inhibited to prevent regrowth of the plant (4). Therefore, effective chemical control of mesquite by aerial applications of 2,4,5–T is dependent on the absorption of the herbicide by the foliage and translocation of toxic concentrations to the dormant buds of the crown.

Methods and Materials

Results herein reported on factors that influence translocation of 2,4,5–T in mesquite were obtained by use of leaflet tests (5), aerial applications, from 1949 to 1952, on 670 five-acre plots, and from cooperative ranch tests at 28 locations in the mesquite belt of south and west Texas (7). In the leaflet tests translocation was determined by measuring the distance that the woody tissues of mesquite were killed below the point of application of the herbicide. No effect was made to distinguish between factors that influenced absorption, translocation or fate of 2,4,5–T. In field plot studies the percentage of plants completely killed within 18 months after treatment was used as a measure of the translocation obtained. Carbohydrate determinations were made on composite samples of sap wood obtained from roots in the crown bud area, and from stems of 5 trees on each date of sampling. In 1950 and 1951 root samples were collected when the first leaves appeared in the spring and thereafter at monthly intervals

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until August 1st or later. In 1952 root and stem samples were collected approximately 15 days prior to the first leaf stage, at the first leaf stage and at monthly intervals thereafter until July 15th. Procedures as outlined in Methods of Analysis of the Association of Official Agricultural Chemists were used for determining the carbohydrate content of the samples. The Munson-Walker general method of determining reducing sugars was followed.

RESULTS AND DISCUSSION

Stage of growth

One of the most important factors governing the effectiveness of 2,4,5–T appears to be stage of growth of the mesquite at time of treatment. Leaflet tests applied at 10-day intervals at Spur from leaf initiation in the spring to mature leaf development in late summer have shown that the greatest transport of 2,4,5–T occurs 50 to 90 days after the first leaves appear in the spring. Maximum translocation of 2,4,5–T during any given year usually took place about 30 days after the plants reached the full leaf stage. Maximum translocation occurred on June 27 in 1949, on June 20, 1950, on May 29, 1952 and on June 1, 1953, or 78, 73, 59, and 61 days, respectively, after the first leaves appeared in the spring.

The results of field plot tests in which aerial equipment was used to apply a low volatile ester of 2,4,5–T at a rate of ½ pound acid equivalent in a 1:3 oil-water emulsion at the rate of 4 gallons per acre were in close agreement with leaflet tests. Applications of $^1/_6$ to 2⅔ pounds 2,4,5–T acid equivalent per acre in various carriers and gallonages failed to give effective kills in dormancy, before full leaf development or during the fall months. Unusually favorable rainfall in August of 1949 apparently prolonged the active growing period of mesquite and reasonably effective kills were obtained when 2,4,5–T applications were made at that time. However in most instances, mesquite plants cease active growth and development about 90 days after the first leaves emerge in the spring and applications of 2,4,5–T made later in the season invariably result in poor or incomplete kills. Apparently the mesquite tissues are capable of absorbing and transporting 2,4,5–T more readily in the spring and early summer than at other seasons.

Plant condition

When the stage of growth for treatment of mesquite is optimum, other factors influencing the effectiveness of 2,4,5–T are dependent on environmental conditions. The growth pattern in perennial plants is influenced by moisture, organic food reserves, soil fertility and other factors which result in cycles of growth and cessation of growth throughout much of the growing season. For 2,4,5–T treatments to be effective there apparently must be a favorable balance of these factors which will support active synthesis and translocation of carbohydrates by a high percentage of the leaves of a normal to heavy foliage cover. The interrelationship between these factors makes it extremely difficult to single out one that may be limiting

plant growth or the absorption and movement of 2,4,5–T at any given time. Some of the factors that appear to influence effectiveness of 2,4,5–T on mesquite will be discussed below.

Organic food reserves in roots and stems

The role that carbohydrate root reserves play in control of perennial weeds has been shown by Aldous (1), Timmons (11), Savage (12), and others. Moreover, the work of Weintraub and Brown (13), and Davis and Smith (3) has shown that translocation of 2,4–D depends on the presence of carbohydrates in the leaves. Crafts (2) has pointed out that for greatest transport of growth regulator substances there must be active growth and movement of organic foods in the plant to the points of storage. Analyses of the sap wood of roots and stems of mesquite at Spur for total and reducing sugars showed a general decline of percent total sugars in roots from the early bud stage to a low point at full leaf stage which was followed by a moderate to rapid build up during the summer months. It is interesting to note in Figure 1 that the total sugar content of the lowest and highest levels varied greatly from one year to the next. Furthermore, the buildup of total sugars did not begin at the same time each year and did not progress uniformly. For instance, the rapid decline in percent total sugars in 1952 from July 1 to 15 followed a drought breaking rain on July 8, and indicates the kind of fluctuations that may take place. More frequent sampling over a greater portion of the growing season is needed to ascertain the effects of drought on changes in

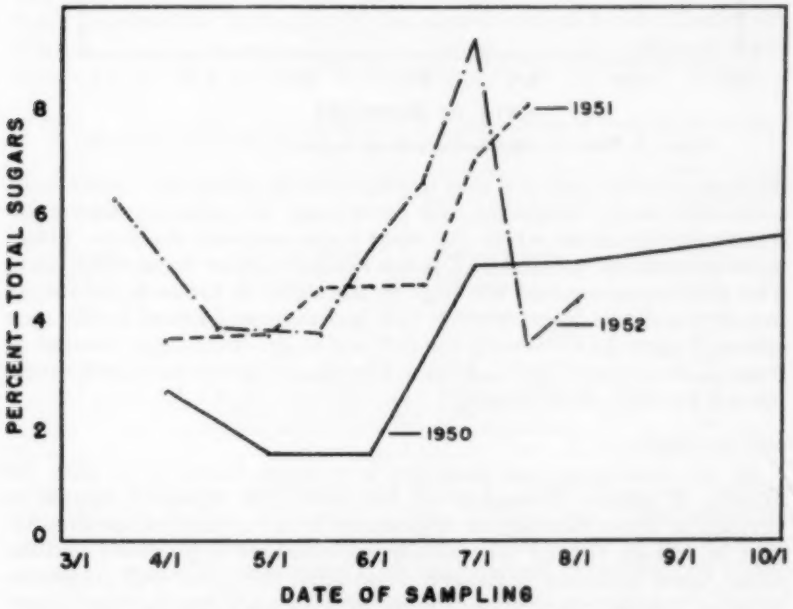

Figure 1. Percent total sugars in roots of mesquite.

food reserves, especially when moisture tends to be irregular. Leaflet studies indicate that greatest translocation of 2,4,5–T takes place when there is moderate to rapid movement of sugars to the roots and tends to diminish when total sugar content of roots remains constant or begins to decline (Table 1). The most favorable conditions apparently occur when there has been a normal to heavy development of foliage and after stem elongation and rapid development of new leaves has ceased.

The relationship between percent total sugars and reducing sugars in the stems for the 1952 season is shown in Figure 2. These pre-

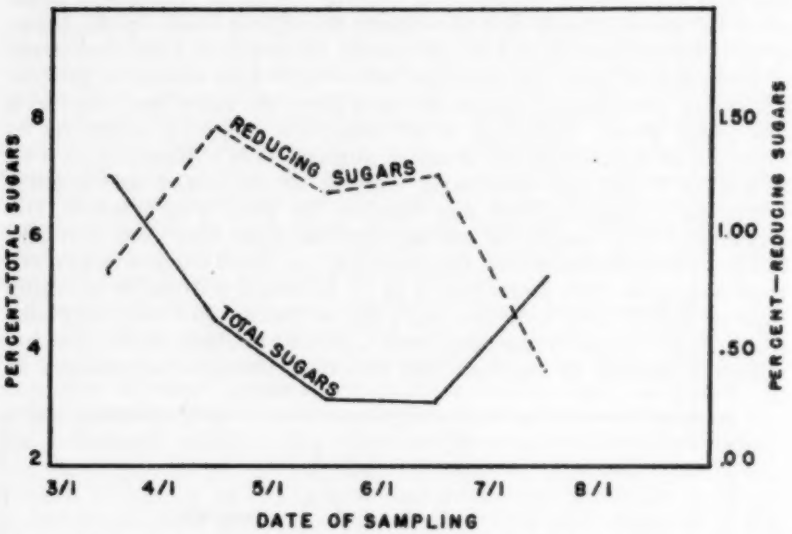

Figure 2. Percent total and reducing sugars in stems of mesquite.

liminary studies indicate that during periods when new leaves and stems are being developed the percentage of reducing sugars increases in the stems while the total sugar content declines. Treatment of mequite with 2,4,5–T is not effective under these conditions. The total sugar content was high in the stems at the early bud stage but dropped to a lower level at full leaf than was found in the root crown (Figure 3). Following the full leaf stage, total sugar content of roots built up rapidly to a peak while that of stems increased slowly toward the end of the season.

Soil moisture

In the Southwest, soil moisture is a major factor governing the growth of plants. Droughts are common and mesquite adapts to periods of water shortage or abundance by a varying foliage density, that is, foliage density increases when moisture is plentiful and declines when moisture is limited. Normally, mesquite will attain the heaviest foliage cover about 20 to 30 days after the full leaf stage. Although some 2,4,5–T translocation takes place under drought

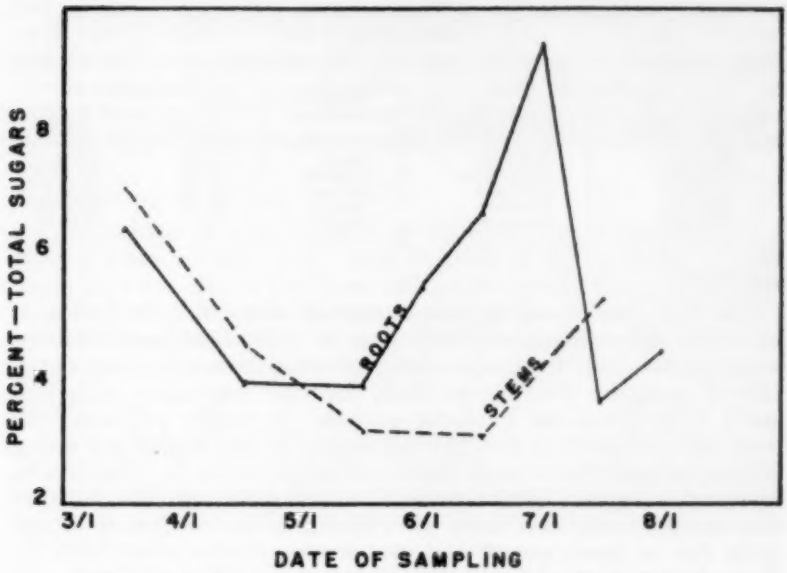

Figure 3. Percent total sugars in roots and stems of mesquite.

conditions when foliage cover is sparse, data from field plots strongly indicate that the accumulation of 2,4,5–T in the crown bud area is not sufficient to prevent sprouting. Similar results with 2,4–D have been reported by McIlvain (10) in control of sage brush. Under conditions of adequate moisture at the leafing out stage, followed by the development of a uniform heavy foliage cover, excellent control of

Table 1. Relationship between the rate of accumulation of total sugars in the roots and translocation of 2,4,5-T.

Season	Date	Rate of accumulation of total sugars	Translocation of 2,4,5-T—inches
1950	Apr. 22–May 9	Rapid decrease	0.75
	June 1–July 15	Rapid increase	5.30
	July 28–Aug. 15	Slow increase	3.20
1951	June 27	Rapid increase	9.80
	July 13	Moderate increase	5.10
1952	May 9	Moderate increase	6.80
	May 15–May 29	Rapid increase	14.90
	June 12–June 23	Moderate increase	4.90
	June 28–July 15	Rapid decrease	2.60
	July 15–July 24	Moderate increase	2.80

mesquite has been obtained with 2,4,5–T. These data also indicate that during periods of drought, light intermittent rains cause new growth cycles which result in a foliage cover made up of leaves in several stages of development with only a small percentage in a stage capable of absorbing and translocating toxic amounts of 2,4,5–T (Table 2).

Table 2. Effect of moisture and foliage cover on percent kill of mesquite, 1949–1952.

Moisture		Foliage cover	Percent kill	
Prior to leafing out	Following leafing out		Tops	Roots
Deficient	Deficient	Sparse	50–90	Trace
Deficient	Intermittent	Variable	70–98	Tr. to 15
Deficient	Adequate	Normal	90–98	20 to 40
Adequate	Normal	Normal	95–98	40 to 98
Adequate	Below normal	Normal	95–98	60 to 98

Soil type

The influence of soil type on the effectiveness of 2,4,5–T was observed in the cooperative ranch tests in 1949, 1950 and 1951. Determinations made 18 months after treatment showed that percentage kills of mesquite growing on sandy loam to deep sandy soils were much higher than for mesquite growing on closely adjoining clay loam soils (Table 3). It is not known definitely why higher percentage kills of mesquite have consistently been obtained on the sandier soils. However, it appears likely that under existing low rainfall conditions that moisture may have been more favorable for the growth of mesquite due to lower runoff and evaporation on the sandy soils (8). Nevertheless, even when conditions were favorable in 1949 the kills of mesquite on clay loam soils were still much lower than those obtained on sandy soils. Other factors that might be responsible for these differences in effectiveness of 2,4,5–T include nature of root systems, depth of sprouting tissues and fertility level.

Table 3. Effect of soil type on per cent total or root kill of mesquite 1949 to 1952 under varying conditions of moisture and foliage cover.

Soil type	Number of locations	Average percent kill
Sandy and sandy loams	10	52.0
Clay and clay loams	10	12.4

Type of growth

Mesquite treated at the various outlying test areas varied from small sprouts and seedlings to large trees. It was found that young plants with stems less than 3 inches in diameter were more effectively controlled than old trees. Lack of vigor, and poor foliage cover may be responsible for lower percentage kills obtained on old trees. Control of regrowth originating from the crown buds of old trees was effective when the new growth reached a height of 4 feet or more and had heavy foliage cover. Apparently there must be a balance of above ground growth with that of the root system for most effective control.

Carriers

In an effort to increase the effectiveness of 2,4,5–T a wide range of oils and oil-water emulsions, as well as water, were evaluated in leaflet and field tests as carriers of 2,4,5–T for control of mesquite. Re-

sults indicate, however, that a 1:3 diesel fuel oil-water emulsion has been equally effective and more economical to use as a carrier than oils. In some instances use of water as the carrier reduced the effectiveness of the 2,4,5–T application. Increasing the volume of carrier from 4 to 12 gallons per acre caused no apparent increase in the percentage kill of mesquite when water, oil-water emulsions or oils were used.

Formulations of 2,4,5–T

Comparisons of a wide range of formulations of 2,4,5–T as suspended acids, amines, and a large number of low and high volatile esters have not shown any great differences in effectiveness in leaflet tests. In field plot studies the low volatile esters and suspended acids were more consistent in killing mesquite than either the high volatile esters or the amine formulations.

Droplet size

Comparisons of droplet sizes varying from very fine droplets of 100 microns to coarse droplets of 500 microns using aerial spray equipment have shown that coarse droplets were equally or slightly more effective than small droplets for control of mesquite and less subject to drift.

Rate of 2,4,5–T acid equivalent used

The amounts of acid equivalent used in field plots studied at 10 locations have ranged from 1/6 to 2⅔ pounds of 2,4,5–T per acre. Results show that ½ pound acid equivalent of 2,4,5–T per acre was equally as effective as the higher rates and generally more effective than ⅓ pound per acre. Amounts below ⅓ pound acid per acre gave poor kills of mesquite under adverse conditions.

Other related factors

Such factors as weather at the time of treatment, including wind velocity and differences in temperature and humidity, did not appear to influence the effectiveness of treatments of 2,4,5–T when applied under field conditions.

SUMMARY

1. Effective and economical control of mesquite is dependent on translocation of a toxic amount of 2,4,5–T from the foliage to sprouting tissues of the crown.

2. Leaflet and field plot studies show that greatest translocation of 2,4,5–T occurs generally during a 50 to 90 day period after the first leaves emerge in the spring. This period is considered to be the most favorable time to treat mesquite with 2,4,5–T.

3. Maximum translocation of 2,4,5–T appears to take place when the total sugar content in the roots is building up at a rapid rate following the low level at the full leaf stage.

4. Minimum translocation of 2,4,5–T appears to occur when total sugars in roots are decreasing rapidly and reducing sugars are relatively abundant.

5. The most effective kills of mesquite have been obtained with 2,4,5–T when there was an adequate supply of soil moisture to develop a uniform heavy foliage cover and 2,4,5–T was applied after rapid growth of new leaves and stems had ceased.

6. Effectiveness of 2,4,5–T aerial applications was reduced when drought restricted growth or intermittent rains caused irregular growth of foliage.

7. Greater effectiveness of 2,4,5–T was obtained on sandy loam and deep sandy soils than on heavy clay soils and on small plants with stems less than 3 inches in diameter than on larger trees.

8. Carriers, whether oils alone or oil-water emulsions or water alone, had no apparent influence on the effectiveness of 2,4,5–T applications when used at 4, 8 and 12 gallons per acre.

9. A rate of ½ pound acid of a low volatile ester of 2,4,5–T in 1:3 oil-water emulsion gave effective and economical kills of mesquite. Increasing the amount of acid did not improve the kill of mesquite.

10. Droplet size of spray material, formulations of 2,4,5–T and weather factors did not appreciably affect the apparent effectiveness of 2,4,5–T. However, these factors must be taken into consideration from the standpoint of safety and ease of handling the herbicide under field conditions.

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The Effect of the Application of Varying Rates of CMU at Different Stages of Plant Growth and Fiber Development on the Yield and Fiber Quality of Irrigated Upland Cotton[1]

E. H. Everson and H. F. Arle[2]

Selective postemergence spraying of cotton in the western irrigated areas for control of weeds has not been widely practiced because of the lack of adequate herbicides and little knowledge of the effect of varying rates of the more promising herbicides on the growth, yield and fiber quality of cotton.

Preliminary work (2) has indicated the effectiveness of 3–(p–chlorophenyl)–1, 1–dimethylurea (CMU) in controlling annual summer grasses *(Echinochloa colonum, E. crusgalli* and *Leptochloa filiformis),* and annual morning glory *(Ipomoea* sp.) in cotton. In these tests CMU was applied at "lay-by" time (after cultivation had to be discontinued because of plant size, but irrigation continued). The results showed rate of application to be very important. Little was learned of the effect of different rates of CMU on yield and fiber quality when the CMU was applied at various stages of plant growth and fiber development.

The use of CMU at low rates as a selective postemergence herbicide for weed control in cotton has been studied by a number of investigators (4, 7, 8, 9). In general their results agree with those of Arle and Everson (2), who reported good weed control without apparent damage to the cotton at rates of 1 to 2 pounds per acre.

Haun and Peterson (5), using C^{14} radio-active ring-labeled CMU, demonstrated that CMU is absorbed readily through the root system of tomato plants and is translocated upward to the leaves. When leaves were treated with C^{14} ring-labeled CMU there was very little movement of C^{14} downward. This suggests that translocation of CMU in plants is mainly in the xylem. They also reported the initial effect of this chemical on plants was a die-back of leaves, and was obvious first on older foliage. At high rates of chemical application, this was followed by progressive chlorosis and retardation of growth ending in the death of the plant. The observations of Haun and Peterson (5) substantiated the findings of Bucha and Todd (3).

The study reported herein was initiated to evaluate the effects of CMU on the yield and fiber properties of upland cotton when applied at different stages of plant growth and boll development.

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[1]Contribution from the Department of Agronomy and Range Management, University of Arizona; and the Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture. Arizona Agricultural Experiment Station Technical Article No. 366.

[2]Agronomist and Plant Physiologist, respectively, Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture; the former was Agronomist at the University of Arizona when this work was completed. Grateful acknowledgment is made to F. Dedera, U.S.D.A., who assisted with the field experiment, and to Edna Lewis, cotton technologist, Department of Agronomy & Range Management, U. of Arizona, who performed all the fiber analyses.

MATERIALS AND METHODS

These investigations were conducted on irrigated cotton at the University of Arizona Experimental Farm at Mesa during the 1953 crop season. A completely randomized block design with four replications was used for each application date. For the first four dates of application, each replication consisted of 5 treatments: 0, 0 (hoed check), 1, 2 and 4 pounds of CMU per acre. For the last two dates of application there were 6 treatments: 0, 0 (hoed check), 0.5, 1, 2 and 4 pounds of CMU per acre. The cotton variety Acala 44, used in this experiment, was planted in rows on 40-inch centers.

The cotton was planted April 20 and the six dates of application and stages of growth were as follows:

1. Seedling stage—May 11
2. Early square stage—June 8
3. Early flower stage—June 29
4. Early boll stage—July 9
5. Lay-by time prior to last cultivation—July 27
6. Lay-by time following the last cultivation—July 27

The CMU was applied in a volume of water equivalent to 40 gallons per acre. The suspension was sprayed as a "blanket" application directly on the soil surface. All plots were irrigated the day following each treatment. Regardless of treatment date, all plots were cultivated prior to each irrigation until lay-by time.

To measure the treatment effect on seed cotton yield, plots 10 (3 rows) x 23.5 feet were harvested. Fiber analysis was run on ten-boll samples collected at random from the plots which were sprayed either before or after the last cultivation on July 27. The ten-boll samples were ginned and the following determinations made on the fiber: Length (Fibrograph method), strength (Pressley index), and fineness (Micronnaire). In addition, maturity dye tests were made on lint samples of the check plots and the 4.0 pounds-per-acre CMU plots from the July 27 postcultivation application.

The effects of CMU on fiber quality, when applied at different stages of fiber development, were studied in a separate test. The cotton for this test was planted on March 25, 1953. Rates and methods of application were similar to those described above. CMU applications were made at lay-by time, July 27, 1953. At intervals before the CMU was applied, 100 blossoms were tagged in each plot. The dates of tagging and the probable stage of fiber development at the time of CMU application were as follows:

June 30—30 days before CMU applied. Fiber approaching the middle of the secondary thickening period when sprayed on July 27.

July 10—20 days before CMU applied. Fiber fully elongated and secondary thickening started when sprayed on July 27.

July 20—10 days before CMU applied. Fiber in the middle of elongation process when sprayed on July 27.

July 27—Fiber development just starting on day CMU applied, July 27.

The above periods of fiber origin and development are very clearly described in a 1947 (1) report.

A random ten-boll sample of each tagging date was collected from each plot at maturity and analyzed in the laboratory for boll weight, precentage of lint, fiber length, fiber strength, and fiber fineness.

The data in all tests were analyzed using the analysis of variance to determine if there was a signfiicant difference between any of the treatment means.

RESULTS AND DISCUSSION

Effect of CMU on cotton growth and yields

The first CMU application was made on May 11, three weeks after planting, when the cotton was in the seedling stage—about 7 inches high with 4 or 5 leaves. With these plots, as with the plots treated later, no effects of the chemical on the plants were evident until after an irrigation followed the application. This is in line with the findings of Bucha and Todd (3) and Huan and Peterson (5), who found that CMU enters the plant through the root system and is translocated upward to the leaves.

Several days after the first irrigation the cotton foliage became chlorotic on all of the treated plots. The degree of discoloration was slight at the 1.0 pound-per-acre rate of CMU, more pronounced at the 2.0 pounds-per-acre, and very severe at the 4.0 pounds-per-acre rate. The initial effect on the cotton leaf was chlorosis along the veins, particularly on the older leaves. This was followed by progressive chlorosis in other leaves and eventual retardation of plant growth. The low rate had little or no persistent effect, whereas the higher rates noticeably retarded the growth of cotton plants. A considerable number of plants died in the plots treated with 4.0 pounds of CMU per acre.

The June 8 (early square stage), June 29 (early flower stage), and July 9 (early boll stage) applications of CMU caused immediate visible effects on cotton plants which were similar to but less pronounced than symptoms described for the first application. The cotton foliage tended to become more chlorotic at the higher rates. These symptoms persisted for three to six weeks following the first irrigation after treatment. The 4.0 pounds-per-acre rate of CMU resulted in partial defoliation of the cotton plants and it was observed that bolls matured more rapidly than on the other plots. At this rate a definite reduction in the number of squares, blooms and bolls was also noted.

The last applications of CMU were made at lay-by time on July 27 prior to the final cultivation, and also on the same date immediately following the final cultivation. A rate of 0.5 pound per acre of CMU and weed-free hoed check were included as treatments in these final two applications. At this late date, CMU had no apparent effect on cotton plants except for some mottling of the leaves at the 4.0 pounds-per-acre rate.

The weight of seed cotton per plot was used as a measure of the crop's tolerance to CMU. Table 1 presents the yield results for the various dates and rates of application. The yield figures represent the average weight of seed cotton in pounds per 10 x 23.5 foot plots.

Table 1. Summary of seed cotton yields (pounds) from plots receiving varying rates of CMU.[1]

Date of application	Check	Hoed check	CMU applications—lbs/A			
			0.5	1.0	2.0	4.0
May 11	10.04	——	——	8.52	6.77*	3.31**
June 8	11.67	——	——	10.47	10.53	9.16
June 29	10.72	——	——	10.19	8.19*	6.15**
July 9	10.04	——	——	9.36	9.66	5.81*
July 27 pre-cultivation	10.66	10.51	10.75	10.39	9.61	9.06*
July 27 post-cultivation	10.14	10.50	10.20	9.23	9.25	7.26**

[1]Yield comparisons should not be made between dates of treatment since the field plot design was not such that the plots between dates could be related.

Yields were usually reduced as the rates of treatment were increased from 0.5 to 4.0 pounds of CMU per acre. With a single exception, the 4.0 pounds-per-acre rate of application resulted in yield reductions which were significant at the 1 or 5% level of probability. In two instances, the 2.0 pounds-per-acre rate resulted in significant reductions at the 5% level of probability.

The chlorosis, retardation of growth, and plant kill which resulted in reduced seed cotton yields as the rates of CMU application were increased, can be explained when the nature of the herbicide, the movement of CMU in the soil and the root zone of cotton at the various stages of growth are considered. CMU at the rates used in this experiment for weed control in cotton is a systemic, selective, translocated herbicide that is absorbed by the roots of plants and moves in the xylem elements to the above-ground parts of the plants. Loustalot et al. (6), in studies involving movement of CMU in the soil, found that the herbicide tends to remain in the surface two inches even when the equivalent of an inch of rainfall follows the application. They found that the movement of CMU was much greater in light, sandy soils. Since the work reported in this paper was conducted on a medium clay loam, the movement of the CMU would probably be restricted to the top several inches of soil.

The first applications of CMU were made on May 11, three weeks after the cotton had been planted. A large part of the root system of the young cotton plants was near the surface when the CMU was applied, and the herbicide was leached into the root zone by the irrigation water following the application. Considerable quantities of CMU were absorbed by the roots and translocated to other portions of the plant causing the chlorosis, stunting, and plant kill. With the June 8, June 29, July 9 and July 27 applications of CMU, the effects were similar to those of the first application but less pronounced. This was probably because the root system was progressively deeper and the aerial portion of the plant larger at each subsequent application.

Weed control

The treatment made May 11 controlled the grass population only during the early part of the season. Within four months after the application, the residual toxicity of the CMU had disappeared, even at the 4-pound rate, and did not control the grass. The summer annual grasses were thicker and more vigorous in the treated plots than in the check plots, possibly because of the open stand and the small amount of shade from the stunted cotton.

The applications made June 9 resulted in good control of the grass throughout the season at the 2- and 4-pound rates, but caused severe stunting of the cotton at those rates.

The applications made June 29 and July 9, when the cotton was in the early flower and early boll stage respectively, gave almost as good control of weeds as those made July 27. However, these early applications caused somewhat more injury to the cotton at the 2- and 4-pound rates of CMU.

All amounts of CMU applied July 27 (lay-by time) gave good control of annual grasses with the exception of the half-pound rate, which gave only fair control. The CMU applied July 27 before cultivation provided somewhat better results than that applied after cultivation. There appeared to have been some lateral movement of CMU by irrigation water where the chemical had not been worked into the soil by cultivation. In areas where irrigation waste water is used on other crops, this movement of CMU would not be desirable.

Fiber quality

In studying the effect of various rates of CMU on cotton when applied at different growth stages, fiber samples from the plots sprayed at lay-by time (July 27—before and after the last cultivation) were analyzed for weight per boll, percent lint, fiber length (upper half mean), fiber strength and fiber fineness (micronnaire). In no instance was there any significant difference between treatments in any test. The results of the maturity dye test, which was conducted with lint samples from the check and 4.0 pounds-per-acre CMU plots, were analyzed and the differences were not found to be significant. This test was run on the two treatments which differed significantly in yield at the 1% level to determine whether or not the CMU would affect the dyeing properties of the fiber.

From the results of the various fiber tests it was concluded that CMU at these rates, when applied at lay-by time, has no deleterious effect on the fiber quality components which were measured. It should be pointed out that since cotton has an indeterminate type of growth, the bolls in the ten-boll samples taken in this test were in various stages of fiber development when the CMU treatments were applied. Therefore, no accurate statement can be made on the basis of these results concerning the effect of CMU on the different stages of fiber development.

The effect of CMU on fiber quality when applied at different stages of fiber development was studied in a separate test. The data in Table 2 show that boll weights and fiber properties were appar-

Table 2. The effect of CMU on fiber quality at different stages of boll development.[1]

Treatment lbs/A	Boll wt.—grams	Percentage lint	Fiber length UHM inches	Fiber strength Pressley index	Fiber fineness micrograms/in
Blossoms tagged June 30—Fiber in middle of secondary thickening period (30 days) when CMU applied July 27					
Check	5.80	35.1	1.10	1040	4.28
Check = hoed	5.70	35.2	1.08	1010	4.39
0.5 lb. CMU	5.88	35.0	1.10	997	4.16
1.0 lb. CMU	5.40	34.7	1.10	1005	4.22
2.0 lb. CMU	5.90	35.2	1.13	983	4.31
4.0 lb. CMU	5.78	35.1	1.06	1033	4.28
L.S.D. 5%	0.52	1.0	0.06	45.2	0.31
L.S.D. 1%	0.69	1.4	0.08	62.5	0.42
Blossoms tagged July 10—Fiber fully elongated and secondary thickening started (20 days) when CMU applied July 27					
Check	5.20	34.2	1.08	993	4.32
Check = hoed	5.08	34.2	1.07	961	4.30
0.5 lb. CMU	5.58	34.4	1.08	967	4.29
1.0 lb. CMU	5.45	35.1	1.07	966	4.32
2.0 lb. CMU	5.35	33.9	1.06	981	4.21
4.0 lb. CMU	5.08	34.4	1.06	961	4.34
L.S.D. 5%	0.72	1.7	0.04	47.2	0.25
L.S.D. 1%	1.00	2.4	0.06	65.5	0.34
Blossoms tagged July 20—Fiber in middle of elongation process (10 days) when CMU applied July 27					
Check	5.83	34.1	1.06	1054	3.98
Check = hoed	5.53	34.1	1.06	1062	3.93
0.5 lb. CMU	5.33	33.0	1.06	1077	3.72
1.0 lb. CMU	5.30	33.5	1.05	1082	3.78
2.0 lb. CMU	5.60	33.1	1.07	1081	3.81
4.0 lb. CMU	5.78	33.6	1.06	1037	3.96
L.S.D. 5%	0.58	1.3	0.04	58.6	0.30
L.S.D. 1%	0.80	1.8	0.06	81.1	0.41
Blossoms tagged July 27—Fiber development just being initiated when CMU applied					
Check	5.65	35.1	1.08	1023	4.41
Check = hoed	5.50	34.3	1.11	978	4.33
0.5 lb. CMU	5.63	33.8	1.12	1033	4.22
1.0 lb. CMU	5.80	34.5	1.10	1012	4.31
2.0 lb. CMU	5.48	33.8	1.09	1025	4.16
4.0 lb. CMU	4.73**	35.5	1.06*	1032	3.74**
L.S.D. 5%	0.65	2.2	0.05	59.0	0.36
L.S.D. 1%	0.89	3.1	0.07	81.7	0.50

[1]All data mean of 4 Reps.

ently unaffected by the CMU treatments if the fibers had reached the stage of development where elongation was underway.

The fiber which developed from the blossoms tagged on July 27, the day the CMU was applied, was affected by the 4.0 pounds of CMU per acre treatment. On this tagging date the differences between treatments were significant at the 5% level for fiber length, and highly significant at the 1% level for boll weight and fiber fineness. In all cases the 4.0 pounds per acre treatment was lower than the other treatments and differed from them at the level of significance mentioned above. It should also be noted that none of the other treatments differed significantly from each other.

From these results we can conclude that CMU at the rates of 0.5, 1.0 and 2.0 pounds per acre has no serious effect on boll weight, percentage lint, fiber length, fiber strength, and fiber fineness during

much of the developmental processes of the fiber or after midpoint of the elongation process. However, during the initial stages of the fiber development, the 4.0-pound rate of CMU reduced boll weight, fiber length and fiber fineness. For this reason and because of the yield depression caused by high rates of CMU, rates in excess of 2.0 pounds of CMU per acre should be avoided where the chemical is intended to be a selective herbicide.

SUMMARY

This study deals with the effect of the application of several rates of CMU at different stages of cotton growth on yield and fiber quality and the effect of CMU on fiber quality when applied at different stages of fiber development.

Applied as a directed spray to the soil and followed by an irrigation CMU was apparently absorbed by the roots and translocated throughout the plant. The initial effect on the cotton plant was chlorosis of the leaves along the veins beginning on the older leaves and was followed by general chlorosis and retardation of growth. The low rates had little or no persistent effects, whereas the higher rates noticeably retarded the growth of cotton plants. Applications of 4.0 pounds per-acre to seedling cotton on May 11 caused considerable mortality. These effects were the same with applications at all stages of growth but were most severe on the earlier stages of growth.

Yields were reduced as the rates of treatment were increased from 0.5 to 4.0 pounds of CMU per acre. In all but one case the 4.0 pound rate of application resulted in significant or highly significant yield reductions. In two of six applications, the 2.0 pound rate resulted in a significant reduction in yield.

Late applications of CMU (at lay-by time) gave good control of annual grasses with rates of 1.0, 2.0 and 4.0 pounds per acre. Earlier applications gave good initial grass control but as the residual toxicity disappeared the grass reappeared. This was especially true with the lower rates of application.

Fiber analyses were run on 10-boll samples of cotton for all treatments from the plots which were sprayed at lay-by-time. In no instance was there any significant difference between treatments in the tests for weight per boll, percent lint, fiber length, fiber strength, and fiber fineness.

In studying the effect of CMU on the different stages of fiber development, it was found that CMU at the rate of 0.5, 1.0 and 2.0 pounds per acre had no serious effect on boll weight, percentage lint, fiber length, fiber strength and fiber fineness after the mid-point in the elongation process. During the initial development stage of the fiber, the 4.0 pounds per-acre-rate of CMU reduced boll weight, fiber length and fiber fineness.

Since rates in excess of 2.0 pounds of CMU per acre reduce yield and do at times affect boll weight, fiber length and fiber fineness, they should be avoided where the chemical is intended to be a selective herbicide.

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The Use of Herbicides in Establishing Legume Seedings[1]

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SEEDLING legumes are slow growing plants and poor competitors. During this period of slow growth, weeds have opportunity to outgrow them, and choke out or seriously damage the legume stand. Many of the important weeds are annual broad-leaved plants such as pigweed *(Amaranthus retroflexus)*, lambs-quarters *(Chenopodium album)*, mustards, and certain annual grasses such as the foxtails *(Setaria* spp.) and crabgrasses *(Digitaria* spp.). Perennial weeds, when present, are a serious problem, but this study was directed primarily at annuals. Since the advent of the combine, volunteer wheat and oats from shattered grain have also become a serious problem in summer legume seedings after small grain.

A common method of weed control in small-seeded legumes is the use of cereal companion or so-called "nurse" crops, which do suppress weeds, but are also serious competitors of the legumes. Their great advantage in the corn belt is that they mature earlier than most weeds, and the legumes can develop without, or with less, competition after July.

Another method of controlling these weeds is by the use of chemical weed killers, either with or without the companion crop. Since the companion crop method precludes any appreciable yield of forage in the seedling year, there is a need for satisfactory herbicides in sowing alfalfa alone. The companion crop method also often fails to control the weeds sufficiently, and herbicides may also have a place under such conditions.

REVIEW OF THE LITERATURE

Most of the experiments with herbicides on seedling legumes have been carried out on legumes underseeded in small grains. In this situation the ester formulations of 2,4–dichlorophenoxyacetic acid (2,4–D) or 2–methyl–4–chlorophenoxyacetic acid (MCP) are to be avoided, as are rates over ¼ pound per acre of the salts (3, 4, 13, 17). Since most of the above authors indicate that some canopy over the legume is needed before phenoxy compounds can be used at all, it was deemed best not to use these compounds on pure stands of seedling legumes.

Recently several workers have tried 3,4–dichlorophenoxyacetic

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acid (3,4–D) and found it less injurious to the legumes than either MCP or 2,4–D (8, 16).

The selective herbicide most often used on seedling legumes is 4,6–dinitro-o-sec-butylphenol (DNBP). Roberts and Blackman (12) have stated, "Good control of annual weeds has been obtained in alfalfa in the seedling stage (with DNBP), and in consequence the establishment has considerably improved." They treated fourteen legumes with DNBP and found alfalfa and red clover to be intermediate in susceptibility as related to the other legumes. Most workers have found it best not to use DNBP as a pre-emergence herbicide. If the legumes are allowed to grow to a height of 6 to 8 inches before spraying, damage to the stand is less liable to occur. Most investigators found that rates of from three-fourths to 2 pounds per acre were effective (2, 6, 7, 10, 13).

Isopropyl–N–phenylcarbamate (IPC) and its 3–chloro derivative, CIPC, have been found to be primarily selective to grass plants. IPC had little effect on alfalfa (5, 9); but, due to its extreme volatility at high temperatures, it has found little use in Ohio. CIPC however, is less volatile and has found wider use. For pre-emergence use, any rate up to 3 pounds per acre has been found to be non-injurious to alfalfa (15). Three to 6 pounds have been reported useful as a post-emergence treatment (14).

Many investigators have used sodium trichloroacetate (TCA) in seedling legumes, usually with only slight injury to alfalfa. Usually, up to 10 pounds of TCA will not damage seedling alfalfa, and will slightly damage small grains (1, 11, 13); although Shaw, *et al.* (14), reported that 4 to 8 pounds of TCA would harm alfalfa.

METHODS

Experiments using herbicides on seedling alfalfa and on alfalfa-red clover mixtures were carried out at The Ohio State University, Columbus, Ohio, from 1951 thru 1955 on several sites. The soil was of the Miami-Crosby-Brookston complex.

The experimental designs were randomized blocks, replicated two to four times.

All applications were made as aqueous sprays, using a bicycle sprayer that maintained a constant pressure of 40 psi. The 2,4–D, 3,4–D, and MCP solutions were applied in 10 gallons of solution per acre, all others in 40 gallons. All sodium 2,2–dichloropropionate (dalapon) solutions included 0.1% of Tween 85 wetting agent.

Summer seedings—In 1951, 1952, and 1953 alfalfa was band-seeded at the rate of about 15 pounds per acre on plowed and prepared land in late July or August. Each year wheat was sown in the plots to simulate volunteer wheat after combining the wheat crop. In 1953 rape was also sown to simulate broad-leaved weeds. The seedings were made in the latter part of July each year.

The herbicide applications were made at one of four stages, not all stages being used each year:

Stage 1. Pre-emergence

Stage 2. Alfalfa at the 2 to 3 true leaf stage
Stage 3. Alfalfa at the 4 to 5 true leaf stage
Stage 4. Alfalfa at the 6 to 8 true leaf stage

In 1953 it became obvious that the rape seeded as a weed was rapidly outgrowing the alfalfa and would be detrimental to the alfalfa stand. The area was irrigated twice so that the rape would form a canopy over the alfalfa; then one-half of each plot was treated with one-fourth pound per acre of the amine salt of 2,4–D on September 16. This killed the rape but also damaged the alfalfa.

Spring seedings—In 1951, 1952, and 1954 alfalfa was band-seeded at 15 pounds per acre on well prepared ground. Oats were seeded in one-half of each plot as volunteer oats at the rate of 6 pecks per acre. The seedings were made in late March or April.

The herbicide applications were made at some of the 4 stages listed above. In 1954, leaf lettuce was sown to simulate broad-leaved weeds.

Spring seedings with a companion crop—In order to compare several herbicides on oats undersown with legumes, alfalfa (10½ pounds per acre), red clover (4½ pounds per acre), and oats (6 pecks per acre) were sown in late March of 1953 and 1954. In order to be certain of a stand of broadleaved weeds, turnips (3 pounds per acre) were included in the 1953 seeding, and leaf letture (3 pounds per acre) was used in 1954.

The herbicide applications were made at one of 5 stages, not all stages being used each year:

Stage 1. Pre-emergence
Stage 2. Oats with 3 true leaves, no canopy over the legumes
Stage 3. Oats fully tillered, canopy formed
Stage 4. Oats jointing
Stage 5. Oats in the boot stage

All plots were rated at various periods after herbicide treatment. At least two people participated in these ratings. All plots were rated for injury to broad-leaved weeds, small grain, and alfalfa. The ratings were made on a basis of 0 to 10; 0 indicating no damage and 10 indicating a complete kill.

RESULTS AND DISCUSSION

Summer seedings—Table 1 shows the results obtained from spraying summer seeded alfalfa. As can be seen, CIPC damaged the alfalfa with little damage to the weeds or wheat unless used pre-emergence. DNBP killed many weeds, but often severely injured the alfalfa. TCA resulted in fairly good control of the wheat, but also injured the alfalfa with little effect on other weeds. In 1953 dalapon was used. That year the alfalfa stand was very poor in the check plots due to the rape competition, and the plots treated with 1 pound of dalapon at the 2-leaf stage had better alfalfa stands than the check plots. Dalapon controlled most of the wheat in all plots but the injury to the alfalfa could not be properly evaluated.

Table 1. Ratings indicating the effect of herbicides on summer seeded alfalfa, on wheat (seeded as a weed) and on broad-leaved weeds. 1951 and 1953 ratings made in April of the following year. 1952 ratings made one month after the final treatment. Each figure is an average of 3 replications in most instances. 0 = no damage, 10 = complete kill

Treatment	Appl. lb/A	Alfalfa stage	1951		1952			1953		
			Alf.	Wheat	Alf.	Wheat	Weeds	Alf.	Wheat	Weeds
CIPC	1	Pre	—	—	1	3	4	—	—	—
	3	Pre	—	—	2	6	6	4	2	4
	—	2-lf.	3	1	—	—	—	5	0	1
	—	4-lf.	2	3	—	—	—	6	0	1
	6	Pre	—	—	3	8	9	4	0	4
	—	2-lf.	2	2	—	—	—	4	0	1
	—	4-lf.	2	2	—	—	—	6	0	3
DNBP	1	2-lf.	1	0	—	—	—	3	4	4
	—	4-lf.	1	0	—	—	—	4	8	2
	2	2-lf.	1	0	10	9	10	—	—	—
	—	4-lf.	2	1	8	8	10	—	—	—
	3	2-lf.	3	3	10	10	9	—	—	—
	—	4-lf.	2	1	9	8	10	—	—	—
TCA	6	Pre	—	—	3	4	5	7	9	0
	—	2-lf.	4	3	7	6	8	7	7	0
	—	4-lf.	8	8	3	3	6	8	10	0
	8	Pre	—	—	2	3	4	7	5	0
	—	2-lf.	5	6	7	7	9	8	9	1
	—	4-lf.	8	8	4	6	8	8	10	0
	10	2-lf.	7	8	8	5	7	—	—	—
	—	4-lf.	9	9	3	5	7	—	—	—
Dalapon	1	Pre	—	—	—	—	—	7	7	1
	—	2-lf.	—	—	—	—	—	3	6	0
	—	4-lf.	—	—	—	—	—	7	6	3
	4	Pre	—	—	—	—	—	5	6	1
	—	2-lf.	—	—	—	—	—	8	10	0
	—	4-lf.	—	—	—	—	—	8	10	1
	6	Pre	—	—	—	—	—	9	9	1
	—	2-lf.	—	—	—	—	—	8	10	0
	—	4-lf.	—	—	—	—	—	8	10	2
Untr.	—	—	0	0	0	0	0	6*	2	0

*In 1953, rape overgrew the plots and shaded out part of the alfalfa stand.

Spring seedings—The results of three years of treating spring seeded alfalfa are shown in Table 2. All CIPC treatments resulted in moderate to severe alfalfa injury. Best results in this experiment were obtained using DNBP. One pound of DNBP used at the 2-leaf stage did not harm the alfalfa and caused a reduction in the incidence of broad-leaved weeds, although it did not harm the oats. One pound used at the alfalfa 4-leaf stage did an even better job of controlling all weeds but the oats, but caused slightly more alfalfa damage. Two pounds of DNBP applied at the 2-leaf stage also resulted in good weed control, but with some damage to the alfalfa. Three pounds of DNBP appeared to be too much, as it generally resulted in fairly severe alfalfa injury. TCA did some damage to the alfalfa without too much damage to the weeds or oats. In 1954, dalapon did not kill the oats until rates were used that also injured the alfalfa. Another very successful chemical was 3,4–D which greatly reduced the incidence of broad-leaved weeds without harming the alfalfa, but also did not harm the oats.

Spring seedings on undersown oats—The substituted phenoxy

Table 2. Ratings indicating the effect of herbicides on spring seeded alfalfa, on oats (seeded as a weed), and on broad-leaved weeds. Ratings made approximately one month after treatment. Each figure is the average of 2 or 3 replications.

0 = no damage, 10 = complete kill

Treatment	Appl. lb/A	Alfalfa stage	1951			1952			1954		
			Alf.	Oats	Weeds	Alf.	Oats	Weeds	Alf.	Oats	Weeds
CIPC	2	Pre	—	—	—	2	4	4	—	—	—
	3	Pre	—	—	—	6	7	9	4	8	4
	—	2-lf.	—	—	—	4	7	4	2	3	2
	—	4-lf.	—	—	—	5	7	5	2	0	3
	6	Pre	—	—	—	8	9	8	8	9	7
	—	2-lf.	—	—	—	—	—	—	4	6	2
	—	4-lf.	—	—	—	—	—	—	2	1	1
DNBP	1	Pre	—	—	—	—	—	—	1	0	2
	—	2-lf.	—	—	—	1	1	5	2	0	10
	—	4-lf.	2	0	10	3	1	9	2	0	6
	2	Pre	—	—	—	1	0	5	0	0	3
	—	2-lf.	—	—	—	3	1	5	2	2	10
	—	4-lf.	4	0	10	6	1	8	1	1	8
	3	2-lf.	—	—	—	5	2	9	—	—	—
	—	4-lf.	6	0	10	5	3	9	—	—	—
	4	Pre	—	—	—	—	—	—	4	0	9
TCA	6	Pre	—	—	—	3	4	3	3	4	1
	—	2-lf.	—	—	—	3	4	3	1	0	2
	—	4-lf.	4	0	0	3	4	4	1	0	1
	8	Pre	—	—	—	3	5	3	1	6	1
	—	2-lf.	—	—	—	6	5	6	2	0	3
	—	4-lf.	5	0	0	5	2	5	0	0	1
Dalapon	2	Pre	—	—	—	—	—	—	1	1	0
	—	2-lf.	—	—	—	—	—	—	0	2	2
	—	4-lf.	—	—	—	—	—	—	0	0	1
	4	Pre	—	—	—	—	—	—	3	3	1
	—	2-lf.	—	—	—	—	—	—	3	6	1
	—	4-lf.	—	—	—	—	—	—	0	2	2
	5	2-lf.	—	—	—	—	—	—	4	8	1
	—	4-lf.	—	—	—	—	—	—	1	3	1
	8	Pre	—	—	—	—	—	—	5	7	1
3,4-D	¼	2-lf.	—	—	—	—	—	—	1	0	8
	—	4-lf.	—	—	—	—	—	—	2	0	8
Untr.	—	—	0	0	0	0	0	0	0	0	0

compounds, 2,4–D amine, 2,4–D ester, MCP amine, and 3,4–D, and a dinitro, DNBP, were compared with each other on alfalfa-red clover seedings in oats in 1953 and 1954. 3,4–D was not used in 1953, and the times of spraying varied slightly from 1953 to 1954, as can be seen in Table 3.

In 1953, oat yields from plots treated at the oat three-leaf stage (average 69.5 bu/A) were significantly better than from those treated at the jointing stage (average 61.5 bu/A). In 1954, oat yields from plots treated at the oat fully tillered stage (average 88.9 bu/A) were significantly better than from those treated at the boot stage (average 79.6 bu/A). In neither year was there found to be any significant difference in oat yields between the plots treated with the amine salt of 2,4–D or the same salt of MCP. DNBP, 2 pounds per acre, significantly reduced the oat yields when used at the boot stage, but no other DNBP treatment injured the oats.

A very heavy stand of turnips was obtained in 1953. This reduced the legume stand and vigor unless the turnips were killed by a herbi-

Table 3. Ratings of legumes treated with various herbicides: Turnips (1953) or lettuce (1954) planted as weeds. 1953 treatments—legumes rated 4/22/54, turnips 8/19/53. 1954 treatments—legumes rated 7/29/54, lettuce 7/9/54. Averages of 3 replications.

0 = no damage, 10 = complete kill

Chemical	Appl. lb/A	Stage 1 (Pre-emer) 1953		Stage 2 (Oat 3-leaf) 1953		1954		Stage 3 (Tillered) 1954		Stage 4 (Jointing) 1953		Stage 5 (Boot) 1954	
		Leg.	Tur.	Leg.	Tur.	Leg.	Let.	Leg.	Let.	Leg.	Tur.	Leg.	Let.
MCP amine	1/8	–	–	3	10	1	9	1	9	3	6	3	9
	1/4	–	–	3	10	5	10	5	10	6	9	2	9
	1/2	–	–	3	10	6	10	5	10	3	8	2	10
	1	–	–	–	–	9	10	6	10	–	–	3	10
2,4-D amine	1/8	–	–	2	10	4	10	3	10	4	7	1	10
	1/4	–	–	4	10	6	8	5	10	4	8	0	9
	1/2	–	–	3	10	7	10	5	10	4	10	2	10
	1	–	–	–	–	8	10	7	10	–	–	4	10
2,4-D ester	1/8	–	–	3	10	4	10	2	10	4	10	4	9
	1/4	–	–	–	–	6	10	4	10	–	–	6	10
	1/2	–	–	9	10	7	10	7	10	8	10	7	10
3,4-D	1/4	–	–	–	–	3	9	3	9	–	–	1	7
	1/2	–	–	–	–	5	10	4	10	–	–	1	10
	1	–	–	–	–	4	10	4	10	–	–	1	9
DNBP	1	–	–	2	7	2	10	2	6	5	2	2	5
	2	3	7	–	–	4	10	5	8	–	–	1	6
Untreated	—	8	0	8	0	0	0	0	0	8	0	0	0

cide. Based on the plot that had the best legume stand as 0, the check plots had an average legume rating of 7.5, indicating the severe injury due to the turnips. Table 3 shows the average legume and turnip or lettuce ratings for 1953 and 1954. Stand counts in 1953 showed the untreated check plots and those that received 1/2 pound per acre of the ester of 2,4–D at any stage to have significantly thinner stands than all other plots.

There was found to be no consistent difference between the amine salts of MCP and 2,4–D with regard to their effects on the legumes or the weeds regardless of the time of spraying, the year, or the rate of chemical used. There was more injury to the legumes as rates increased from 1/8 pound per acre to 1/2 pound, and slightly more injury at the earlier stages of treatment than at the later ones when a canopy had formed. The same statement applies to the ester of 2,4–D, except that the injury was more severe at all stages and rates except 1/8 pound per acre than where the salt was used. The higher rates of 3,4–D caused less injury than those of the other phenoxy compounds, while causing equal lettuce damage. DNBP was used very successfully at 1 pound per acre, causing greater kill of the weeds when used before a canopy of oats had formed.

Hay yields on the 1953 plots were taken in the spring of 1954. Because of the effect of the turnips, the yields from the check plots were very low. Plots that had received MCP, 2,4–D amine, 1/8 pound of the ester of 2,4–D or DNBP yielded 3 to 4 times as much hay as the check plots. This was not true where 1/2 pound of the ester was used.

SUMMARY AND CONCLUSIONS

The use of herbicides during the springs and summers of 1951 thru 1954 was studied in legume seedings both with and without companion crops, to kill weeds and permit better establishment of the legumes.

Pure stands of alfalfa were seeded during the summer or spring of 1951, 1952, 1953 and 1954. In each summer seeding wheat was seeded in part of each plot to simulate volunteer grain dropped from a combine. In the spring seedings oats were seeded in part of each plot to simulate a volunteer oat population. The alfalfa was treated either pre-emergence or at the 2 to 3 true leaf stage, the 4 to 5 true leaf stage, or the 6 to 8 true leaf stage. The chemicals used were CIPC, DNBP, TCA, dalapon and 3,4–D. Not all treatments were used each year.

In the summer seedings CIPC, TCA, and dalapon were found to injure the alfalfa as much as the weeds in most instances. DNBP at 1 to 3 pounds per acre killed most of the weeds at the 2 and 3 pound rates, but also caused some injury to the alfalfa.

When used on the spring seedings, 3,4–D at ¼ pound per acre post-emergence, and DNBP at 1 pound per acre post-emergence killed most of the weeds without harming the alfalfa. Higher rates of DNBP caused slightly more damage to the alfalfa. CIPC, TCA and dalapon acted as they had in the summer seedings, injuring the alfalfa and the weeds equally.

No treatment was found which successfully killed the grains without injuring the alfalfa, although dalapon showed some promise.

Herbicides were also used on an alfalfa and red clover mixture seeded in oats. The turnips planted as weeds in 1953 were very heavy and suppressed the stand and greatly reduced the yield of the forage. Thus, any herbicide that controlled the turnips benefited the forage. The chemicals used were MCP, 2,4–D amine and ester, 3,4–D and DNBP. Treatment with phenoxy compounds when the oats were at the 3-leaf stage or the fully tillered stage resulted in significantly better oat yields than treatments at the jointing or the boot stages.

Due to the suppression of the weeds, legume stands were much better where the 2,4–D and MCP amine compounds were used at the rate of one-eighth pound per acre. Higher rates were harmful unless a heavy canopy of weeds existed. One-eighth pound of the ester formulation of 2,4–D was fairly good, but one-half pound was detrimental to the stands. The hay yields from the MCP and 2,4–D plots, other than ½ pound per acre of ester, were far superior to the yields from the untreated checks. Plots treated with MCP amine reacted very similarly to those treated with 2,4–D amine, regardless of the time of spraying, the year, or the rate of chemical used. 3,4–D was similar to but safer than 2,4–D on the legumes at higher rates.

The use of DNBP at 2 pounds pre-emergence or one pound early post-emergence resulted in increased legume stands, vigor and yield because it suppressed weed growth without damaging the legumes. One or 2 pounds per acre at the oat jointing stage was too little and too late.

It is felt that DNBP at the present time offers the best opportunity for chemical weed control in legume seedings. The substituted phenoxy compounds may have a place where there is a very severe weed stand that forms a canopy and may shade out the legume stand. Of these compounds, 3,4–D appears to be the safest, but more work is needed.

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Chemical Control of Big Sagebrush and Its Effect Upon Production and Utilization of Native Grass Species[1]

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AS EARLY AS 1946, a limited study conducted in Oregon (5) showed big sagebrush *(Artemisia tridentata* Nutt.) to be susceptible to the sodium salt of 2,4–D. Cornelius and Graham (3) stated that big sagebrush was highly susceptible or hypersensitive to 2,4–D. Kissinger, Hull and Vaughn (7), reporting on experiments conducted at the Beaver Rim area near Lander, Wyoming, found that the isopropyl and amyl ester of 2,4,5–T consistently gave higher kills for a given amount of chemical. One pound acid equivalent (hereafter referred to as pounds acid) of 2,4,5–T usually gave somewhat higher kills than two pounds acid equivalent of 2,4–D.

Hull and Vaughn (4) stated that the type and amount of chemical which killed two-thirds or more of the brush plants varied with the carrier and the season. The butyl ester form of 2,4–D gave better results than mixtures of 2,4–D and 2,4,5–T or the contact sprays.

Hyder (6), working in Oregon, stated that butyl ester of 2,4–D gave the best control for the money, even though the growth regulator, 2,4,5–T, killed more brush. Colorado workers (1) showed that volatile esters of 2,4–D gave more economical control of big sagebrush than the low-volatile esters. The herbicide 2,4,5–T made a poorer showing as an economical means of control, was less effective than 2,4–D, and more costly.

Bohmont (2), observing the effects of chemicals 75 days after treatment, noted that a low-volatile (tetrahydro furfural) ester of 2,4–D, at two pounds acid per acre, caused the most observable toxicity. While 2,4,5–T treatments suppressed seed head development, the plants partially recovered and seed heads formed during the growing season, compared to the 2,4–D treatment which prevented seed heads from forming.

Increase in production of native forage has been reported on all sites where chemical control has been used. Average air-dry herbage production near Lander (7) showed 222 pounds per acre on untreated land; 490 pounds per acre with 58 percent sagebrush control; 553 pounds with 66 percent sagebrush control; and 645 pounds with 97 percent sagebrush control. Native grass production, on an experimental area near Lander, was increased two to three times by killing 60 to 97 percent of the sagebrush. The increased production and more accessible forage supply on the sprayed areas were utilized almost twice as heavily as on unsprayed areas. Bohmont (2) stated

[1]This is a cooperative project between the Wyoming Agricultural Experiment Station, the Bighorn Forest Permittees Association, and the U. S. Forest Service. The article is based on a thesis submitted by Harold P. Alley in partial fulfillment of the requirements for the degree of Master of Science at the University of Wyoming, March 1955. Published with the approval of the Director, Wyoming Agricultural Experiment Station as Journal Paper No. 71.

[2]Formerly graduate student, Department of Agronomy, University of Wyoming; now Research Assistant, Department of Agronomy, University of Wyoming.

that grass production increased as percentage of sagebrush control was increased. One year after treatment there was 38 percent more grass production in the 50–75 percent controlled area than in the untreated areas; 62 percent more in the 76–95 percent controlled area; and over 136 percent in the 96–100 percent controlled area. In the area treated for two years with 98 percent sagebrush control, there was an increased production of 212 percent more grass, compared to the untreated check. Hyder (6) shows an increase of 300 to 400 pounds of herbage per acre during the first year following the spraying year, and 500 to 700 pounds above the unsprayed production during the second year.

Although there has been considerable research on the use of selective herbicides for the control of big sagebrush, there are still several phases of control which remain unanswered. The success of chemical sagebrush control has been well established, but there is an urgent need to follow the complete vegetative changes which may occur over a period of years as a result of the control measures.

METHODS AND MATERIALS

In an effort to better understand the various phases of chemical sagebrush control, an experimental area (approximately 8200 feet elevation with an average annual precipitation of 20 inches) was located in the Bighorn Mountains of northern Wyoming. Typical sagebrush areas were selected which were grazed by cattle and one grazed by both cattle and sheep. The cattle range was located on South Park Allotment, Paint Rock District, Bighorn National Forest; and the sheep and cattle range was located on H. W. Flitner land (Bald Ridge), Shell, Wyoming. Sagebrush clumps averaged 26.9 inches in height by 30.0 inches in diameter, and 32 clumps per square rod.

An area of 310 acres of big sagebrush rangeland was subdivided into 1500 x 200 feet (7.5 acres) plots with buffer strips between plots of 1500 x 100 feet (3.5 acres). The strips served to minimize the possibility of chemical drift between plots. The following chemical treatments were made:

Treatment	Pounds acid equivalent per acre
Butyl ester of 2,4–D	One, two and three
Tetrahydro furfural ester of 2,4–D	One and two
Pentyl ester of 2,4,5–T	One
Pentyl ester of 2,4,5–T and butyl ester of 2,4–D	One and two (one-half each)

All chemicals were applied by airplane on June 16 and 17, 1952; one half of each plot was retreated on June 19 and 20, 1953 with two pounds acid of butyl ester of 2,4–D. All chemicals were applied in diesel oil at a uniform volume of two gallons per acre at a total cost of $2.66 to $6.48 per acre; $1.50 for plane and pilot and remainder for materials. Chemical treatments were located at random, two replications of each treatment being duplicated in two locations.

The plot arrangement was designed so that all of each plot was sprayed the first year, and one-half of each experimental area retreated the next year. A series of check plots were also included which were left untreated; another group received only one year's application.

An extensive vegetative survey was made at the time of chemical application in 1952 and in the spring of 1953 and 1954. Ground cover was determined by the point quadrat method, and basal density by the 100 square centimeter transect method. One hundred quadrats were located at random in each plot, with a total of 28,000 points recorded for the ground cover determination, and 28,000 square centimeters observed for the basal density study. Production was determined in the fall (September 1, 1953 and 1954). Measurements for production determinations were made in two permanent, 84-square foot exclosures built in each plot. By measuring the abundance as determined by the number of occurrences of a species in 100 square centimeters of transect, and by measuring the maximum leaf height of species in inches, it was possible to determine a volume production as follows:

Volume production = Species' frequency per 100 square centimeters x species' maximum leaf height

In the fall of 1954, a circle 2.5 feet in diameter, was located in each exclosure and clipped to determine the forage production. The yield in grams of each plot was multiplied by 20 to convert the production to pounds per acre. Utilization by treatment replication was determined by leaf height measurements. Following is the formula used for percent utilization:

$$\text{Percent utilization by species} = \frac{\text{Ungrazed height} - \text{grazed height}}{\text{Ungrazed height}} \times \frac{\text{Grazed frequency}}{\text{Ungrazed} + \text{grazed frequency}}$$

The efficiency of various chemical applications was determined by counting 200 sagebrush clumps selected at random in each plot one year after chemical application. A total of 11,200 clumps was classified for the entire area. Each sagebrush clump was classified as alive, dead, or partly dead. It was believed that partly dead clumps (between 50–99 (percent defoliated), as well as completely dead sagebrush, should be considered in evaluating the chemical used. Partly dead sagebrush was considered as equal to one-half of a totally dead sagebrush plant. Since the efficiency of the various chemicals differed, it was possible to obtain sagebrush control ranging from zero control for the untreated plots to as high as 95 percent kill resulting from one application of chemical (Figure 1). By sampling the vegetation within an area, it was possible to determine the influence of various degrees of sagebrush control upon the grasslike species, forbs, shrubs, and bare area as compared with the untreated area. Data was summarized on the basis of 0, 50–75, 76–95, and 96–100 percent of sagebrush control.

Figure 1. Area on right, zero percent control or check area; area on left, a 96–100 percent control area, sprayed with 3 pounds 2,4–D ester.

EXPERIMENTAL RESULTS

The percentage of sagebrush control resulting from one application varied from 55 percent for the least effective chemical, to 95 percent control for the best treatment, shown in (Figure 2). One pound acid per acre of 2,4,5–T ester resulted in the lowest percent sagebrush kill (55 percent which was significantly less than the 2,4–D treated plots) and the highest cost to kill 100 clumps (15.5 cents). The most efficient application was one pound acid per acre of 2,4–D volatile ester, costing 8.3 cents to control 100 clumps. This application, however, gave only 62 percent control. The highest control resulting from a single treatment was from three pounds acid per acre of 2,4–D volatile ester, which gave 96 percent sagebrush control. Three pounds acid per acre of 2,4–D volatile ester cost 10 cents per 100 sagebrush clumps controlled.

The low volatile ester, although being initially more toxic to the foliage than the volatile ester, did not give significantly higher sagebrush kills at either the one or the two-pound rates. A single application of two pounds 2,4–D ester or a combination of one pound 2,4–D and 2,4,5–T controlled 75 percent or more of the sagebrush at a cost of 9 to 9.5 cents per 100 clumps controlled. Applications of one pound acid per acre of volatile ester, and two pounds acid per acre of 2,4–D volatile ester applied the following year, controlled over 98 percent of the sagebrush clumps at a cost of 12.7 cents per 100 clumps controlled.

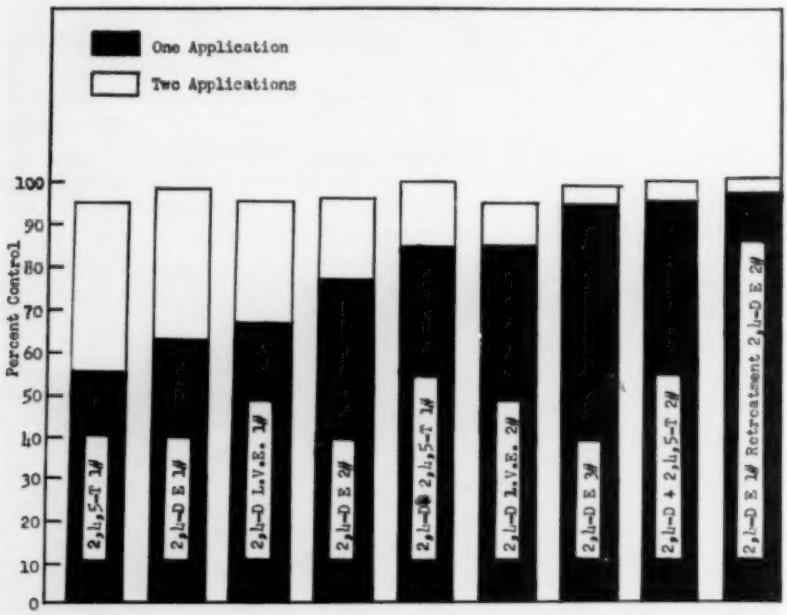

Figure 2. Percentage of big sagebrush controlled with 2,4–D, 2,4,5–T and mixtures of 2,4–D and 2,4,5–T with one application in 1952. Two applications include original treatments plus two pounds 2,4–D ester per acre sprayed the following year. Applications made in 1951 and 1952 to plots treated with one pound 2,4–D ester followed by 2 pounds 2,4–D ester.

There is no statistical difference in the percent of sagebrush killed between one pound acid per acre of 2,4–D ester and one pound acid per acre of 2,4,5–T ester, although cost to control 100 clumps was almost twice as much for the 2,4,5–T.

Table 1 shows the summary of the vegetative composition of big sagebrush rangeland, as influenced by varying degrees of chemical control, one and two years after the original treatment. Vegetative ground cover and basal density of sagebrush grass type rangeland is shown when 0, 50–75, 75–95, and 96–100 percent of the sagebrush has been controlled.

Table 1 and Figure 3 show that ground cover of grasses increased as the percentage sagebrush control was increased. Where there was no sagebrush control, grass and grasslike species made up 20.6 percent of the ground cover, compared with 35.3 percent ground cover where 96–100 percent sagebrush was controlled. The increased ground cover of grasses is highly significant when comparing the 50–75 percent controlled area to the untreated area, and comparing the 96–100 percent controlled area to the 50–75 percent controlled area; significance of ground cover at 5 percent level is also shown when comparing the 96–100 percent control area to the 76–95 percent controlled area. Although the percentage ground cover of forbs decreased as the percent of sagebrush control increased, there was no

Table 1. Percentage vegetative composition of big sagebrush grass type rangeland as influenced by varying degrees of chemical control.

Species	Ground cover						Basal density					
	Percentage sagebrush control						Percentage sagebrush control					
	0	50–75	76–95	96–100	L.S.D. .05	L.S.D. .01	0	50–75	76–95	96–100	L.S.D. .05	L.S.D. .01
Shrubs												
Big sagebrush (*A. tridentata*)	58.8	54.6	53.8	46.6	8.05	14.70	3.3	2.6	2.5	2.0	—	—
Grass and grasslike species												
Idaho fescue (*F. idahoensis*)	7.3	6.5	10.0	12.8	—	—	9.2	8.2	9.9	11.0	—	—
Bluegrass (*Poa* spp.)	7.5	9.7	10.9	13.7	—	—	6.7	8.8	9.5	10.5	—	—
Other species[1]	5.8	10.3	9.2	8.8	—	—	5.2	8.0	8.8	8.7	—	—
Total	20.6	26.5	30.1	35.3	4.1	5.8	21.1	25.0	28.2	30.2	2.8	3.9
Forbs	14.2	12.7	10.4	10.9	—	—	15.2	13.6	10.0	9.8	—	—
Bare area	6.4	6.2	5.7	7.2	—	—	60.4	58.8	58.3	58.0	—	—
L.S.D. Grass (species × control classes)	—	—	—	—	7.0	9.9	—	—	—	—	4.8	6.7

[1]Other Species: Alpine timothy (*Phleum alpinum*), mountain rush (*Juncus* sp.), oval headed sedge (*Carex* sp.), subalpine needlegrass (*Stipa columbiana*).

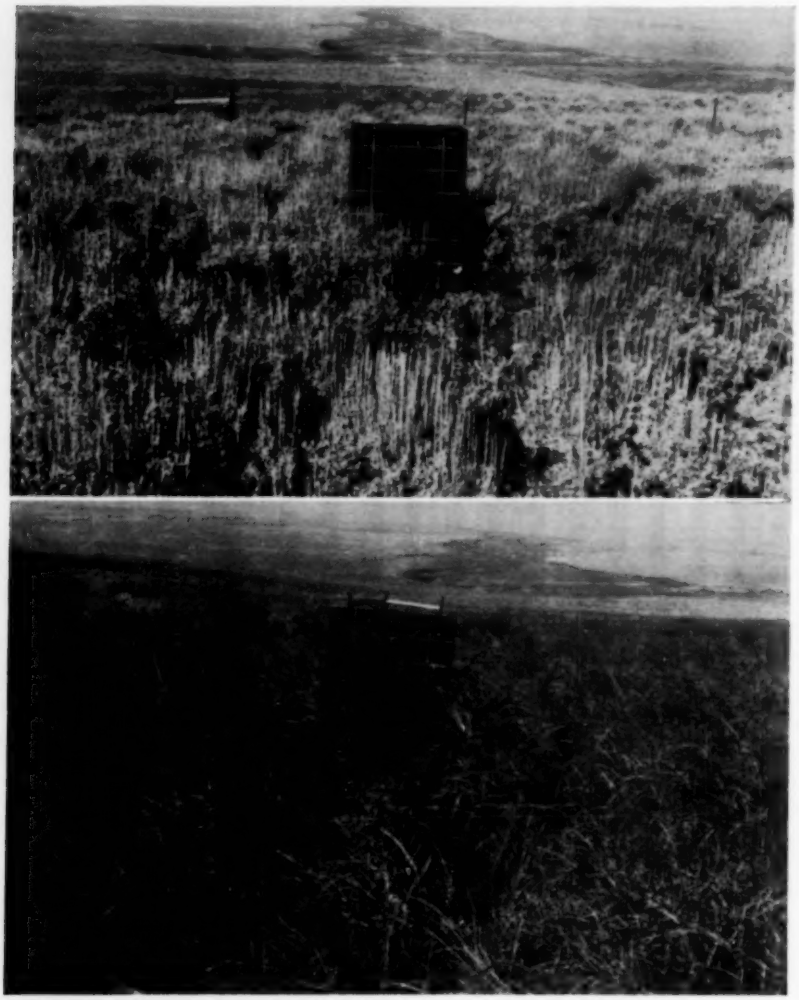

Figure 3. Two adjacent plots as they appeared in the fall of 1955. Top,—check area. Bottom—sprayed with one pound 2,4–D ester 1952 and retreated with two pounds 2,4–D ester 1953.

significant difference between any of the areas, whether treated or not. The amount of bare area shows little difference between 0 and 96–100 percent sagebrush control.

Basal density shows a similar trend, in that, as sagebrush control increased the basal density of forbs decreased. There is very little change in basal density of big sagebrush, because dead sagebrush clumps as well as live sagebrush clumps were recorded as being part of basal density. The basal density of grasses showed significance at all levels of control when compared to the untreated check area, and

comparing 96–100 percent control area to the 50–75 percent control area. Significance was also shown at the 5 percent level between all degrees of control except the 76–95 percent, compared to the 96–100 percent control treatment. The basal density counts show bare area remaining approximately the same.

The air-dry grass production shown in Table 2 is an average of the production obtained in the fall of 1953 and 1954. The grass production was increased as the percentage of control increased. There was a range of 480 pounds of air-dry grass production on untreated check to 1347 pounds on the 96–100 percent control plots (Figure 4). Computed on the basis of the untreated check, there was

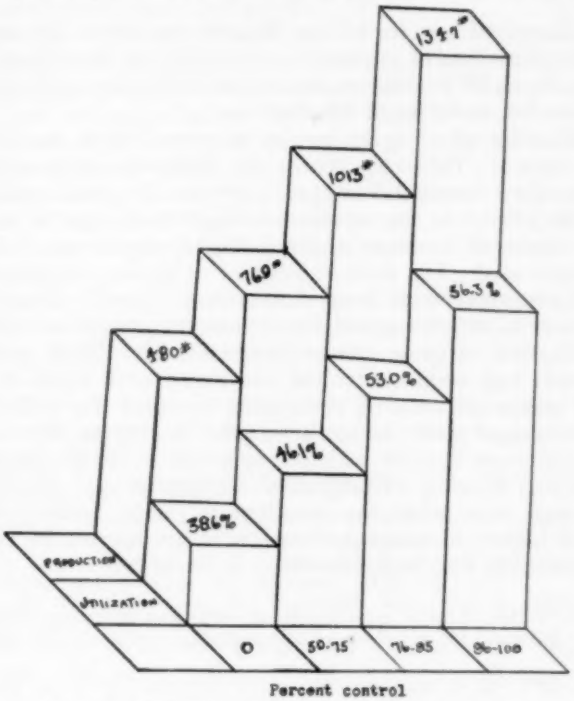

Figure 4. 1953–54 average air-dry grass production and utilization of grasses on sagebrush control plots sprayed in 1952–53.

60 percent more grass on the 50–75 percent controlled area than in the untreated plots; 111 percent on the 76–95 percent controlled plots; and 180 percent more grass production on the 96–100 percent controlled plots. Sagebrush control ranging between 76 and 95 percent gave the optimum return per dollar invested. Although the average treatment cost of sagebrush control in the 50–75 percent group was $3.45, compared to $4.75 in the 76–95 percent range, the five-year amortized cost per ton of hay increase was $8.16 for the 50–75 percent control as compared to $5.38 for the 76–95 percent con-

Table 2. Air-dry grass production, livestock utilization, and cost for various percentages of big sagebrush control.[1]

Percent sagebrush control	Total grass production pounds per acre	Percent livestock utilization	Pounds grass used per acre	Average treatment cost		Five year amortized cost per ton hay increase	
				One application	Two applications	One application	Two applications
0	480	38.6	185	——	——	——	——
50–75	769	46.1	354	$3.45	——	$8.16	——
76–95	1013	53.0	537	4.75	$7.73	5.38	$8.78
96–100	1347	56.3	758	——	8.27	——	5.76

[1]Cost is average of all treatments which produced the given percentage of control and does not indicate the cost of the most economical chemical.

trol. The amortized cost for killing 96–100 percent of the sagebrush with two applications of chemicals, exceeded the amortized cost of controlling 76 to 95 percent of the brush with one application, by only 38 cents for each ton of hay increase.

The utilization of all grass species increased with the increased sagebrush control (Table 3). While the intensity of use varied between years, there was a definite tendency for the grass species to be more heavily grazed as the amounts of sagebrush control increased. By single degree of freedom analysis, highly significant differences were obtained where less than 75 percent of the sagebrush had been controlled, compared with areas where more than 75 percent of the sagebrush was killed. However, there were no statistical differences in the utilization of grass species in areas where 76–95 percent of the sagebrush had been controlled compared with areas of 96–100 percent of sagebrush control. Averaging together the utilization of sheep-cattle range and cattle range, the bluegrass *(Poa secunda* complex) was most heavily utilized, followed by Idaho fescue *(Festuca idahoensis* Elmer.), wheatgrasses *(Agropyron* spp. Gaertn.), and the least used was subalpine needlegrass *(Stipa columbiana* Macoun.). The higher increased utilization of needlegrass in 1954 over 1953 was probably due to its increased abundance.

Table 3. Utilization of major grass species on cattle and on sheep-cattle rangeland in 1953 and 1954 as influenced by varying percentages of big sagebrush control.

Grass species	Percentage of control								All treatments		
	0		50–75		76–95		96–100		Average use[1]		Average two years
	1953	1954	1953	1954	1953	1954	1953	1954	1953	1954	
Idaho fescue (*F. idahoensis*)	36.7	27.8	38.4	53.3	49.3	54.2	60.4	61.0	41.1	49.1	45.1
Bluegrass (*Poa* spp.)	53.4	43.5	48.9	49.0	52.4	62.8	51.4	62.0	50.6	54.3	52.4
Wheatgrass (*Agropyron* spp.)	35.0	31.8	38.2	44.5	43.2	53.7	46.0	49.4	41.4	44.6	43.0
Needlegrass (*S. columbiana*)	5.7	39.2	13.7	20.5	22.5	51.4	——	54.0	14.0	41.3	27.6
Weighted average utilization	41.8	35.4	44.6	47.6	49.4	56.5	54.5	58.1	46.1	49.4	47.8
Weighted utilization average years	38.6		46.1		53.0		56.3		——	——	——
L.S.D. .05									25.0	9.1	4.2
L.S.D. .01										16.7	6.2

[1]Average use (species × years) L.S.D. .05 = 8.8; .01 = 12.7.

SUMMARY AND CONCLUSIONS

1. While 2,4–D and 2,4,5–T may be used for the control of big sagebrush, 2,4–D is the most effective and economical.
2. There was no difference in the final sagebrush control resulting from the two-pound acid per acre treatment of either the volatile or low-volatile esters of 2,4–D.
3. One application of chemical is economical if 75 percent or more of the brush is killed. Two applications would insure maximum control at an increased cost.
4. Native grass production was increased as control of sagebrush increased. Most grass production was observed in the 96–100 percent sagebrush controlled areas.
5. Percentage vegetative composition of grasses increased as control increased. A highly significant increase was shown between all sagebrush controlled areas as compared to the zero controlled.
6. The total forb population was only slightly affected by chemical treatments over a two-year period. Resistant forbs increased in abundance as susceptible forbs were removed.
7. Control of 76 to 95 percent of sagebrush appears to be the logical amount of sagebrush which should be controlled to give the maximum return in production and livestock utilization per dollar invested.
8. Sagebrush on rangeland, with a good understory of grasses, can be controlled with the owner realizing returns over investment within a span of three to four years.

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Sodium Trichloroacetate—Centipede Grass Killer[1]

C. B. Owens[2]

Centipede grass *(Eremochloa ophiuroides)* is a major pest to pasture lands throughout northwest Florida. It is a low growing perennial which spreads by stolons. In appearance it is intermediate between carpet grass and Bermuda grass; it has shorter nodes than the latter and makes a dense mat of creeping stems and leaves. Although it is a pest to pastures it is very desirable as a lawn grass. The fact that it is adapted to a wide range of soils and fertility levels provided sufficient moisture is present, makes it ideal for this purpose. In pastures it is undesirable because of its low feed value, and its dense aggressive growth which tends to crowd out desirable plants.

Presently, no data is available on the eradication of this weed with chemicals. A cultural method that has been practiced is to "flat break" the infested area during the hot dry months of summer and continuously keep it disced until the plants are dead. This may require many weekly discings, depending on weather and soil conditions. Because the plant grows vigorously and sometimes produces seed, light tillage is ineffective and often brings about the dissemination of the propagules.

The purpose of this investigation was to determine, (a) the effects of an herbicide on centipede grass, (b) how soon after treatment the area could be seeded with a desirable plant, and (c) whether tillage after treatment would increase kill.

Materials and Methods

Treatments of centipede grass were made in April of both 1953 and 1954 with 50, 75, 100, 125 and 150 pounds of sodium trichloroacetate (STCA—commercial material) in 100 gallons of water per acre. The soil was of the Norfolk series. The sod was not disturbed before treatment. Each chemical treatment was replicated twice. In order to determine the effects of tillage and how soon the treated area could be reseeded one replication from each chemical treatment, after the full effect of the chemical was exhibited, was plowed, fertilized, and seeded to bahia grass *(Paspalum notatum)*. Tillage treatments in 1953 and 1954 were made 46 days following chemical treatment. Percent control was based on untreated cultivated plots. The effects of the herbicide in 1953 and 1954 were determined forty-six days following application. The effects of the herbicide with tillage were determined forty-five days following tillage.

Twenty hours following the 1953 treatments .21 inch of rain occurred. In 1954 no rain occurred for thirteen days following treatments.

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[1]Contribution from the Department of Agronomy, Florida Agricultural and Mechanical University, Tallahassee, Florida. Experimental quantities of sodium trichloroacetate were supplied by the Dow Chemical Company. Their cooperation is gratefully acknowledged.

[2]Associate Professor of Agronomy.

RESULTS AND DISCUSSION

The results of this experiment indicated that STCA was highly effective in ridding centipede grass from pastures. Following the 1953 treatments the light rain that occurred was desirable in that it washed the herbicide down into the soil where it could come in contact with the plant roots, thus making it act more quickly and perhaps more effectively.

Fifty pounds of STCA per acre without cultivation were not effective even with the aid of the light rain (Table 1). A greater kill was obtained with the 75-pound rate but, as with 50 pounds, after a few

Table 1. Effect of sodium trichloroacetate with and without tillage on centipede grass.

Appl. lb/A	Percent centipede grass control			
	1953		1954	
	Cult.	Not cult.	Cult.	Not cult.
None	0	0	0	0
50	100	55	100	50
75	100	78	100	75
100	100	100	100	100
125	100	100	100	75*
150	100	100	100	100

*The presence of droppings on plot prevented the herbicide from coming in contact with grass.

months the remaining live stolons produced sprouts that engulfed the entire treated area. Both rates affected the general metabolism of centipede grass. The most noticeable effect was chlorosis and eventual browning of the entire leaf and some stems. The stems not killed were of a darker green color than the check. They appeared to remain dormant for several weeks after which numerous sprouts were observed.

The lowest effective rate of STCA without cultivation on centipede grass was 100 pounds per acre. This rate was one hundred percent effective in killing the stems and roots.

Although no rain occurred for 13 days following the 1954 treatments, the results were essentially the same as those obtained in 1953. This variation from the 1953 treatment was advantageous in that it allowed for observation of the chemical under more adverse conditions. Being a contact type herbicide, it immediately caused burning of the leaves, but no other injuries were apparent until about 16 days later at which time the effects of the various rates were the same as those of 1953.

Forty-six days following the treatments, growth of coffee weed *(Cassia tora* L.) and nut grass *(Cyperus rotundus)* were observed on all treated plots. The growth of coffee weed seedlings indicated that the herbicide had either leached down below the root zone or decomposed, or both. At this time one replication from each rate was tilled and seeded to bahia grass. The tillage resulted in complete kill of centipede sprouts on plots treated with 50 and 75 pounds of STCA. The undisturbed plots treated with the 50 and 75 pound rates

on the other hand, had sprouts varying in length from 2 to 6 inches long. The amount of chemical needed to eradicate centipede grass was reduced by one half with the aid of one tillage operation.

An excellent stand of bahia was obtained on all treated plots. This indicated that a desirable grass could be established on an area treated with STCA six weeks following treatment.

SUMMARY

An experiment was conducted to determine the effect of sodium trichloroacetate on centipede grass and whether tillage after treatment would increase the effectiveness of the herbicide. The results of this experiment may be summarized as follows:

1. Sodium trichloroacetate at the rate of 100 pounds (commercial material) per acre and up was effective in eradicating centipede grass without tillage.
2. The herbicide at 50 pounds and 75 pounds per acre without tillage reduced the stand of centipede grass by 50 to 75 percent, but the remaining sprouts engulfed the entire treated area.
3. Fifty pounds per acre of the herbicide with tillage was 100 percent effective in eradicating centipede grass thus reducing the amount of chemical needed by one-half.
4. The treated areas were successfully seeded to bahia grass 1½ months after treatment.

News and Notes

A conference on non-agricultural uses of herbicides was held in Jackson, Mississippi on February 28, 1956. The conference was sponsored jointly by the Mississippi Agricultural Extension Service and Experiment Station. Topics discussed included use of soil sterilants, rights-of-way weed and brush control, control of weeds and brush on drainage canals, proper application techniques and equipment.

A meeting of the weed control section of the Tri-States Agronomy Conference was held in Ithaca, New York on November 16, 1955. Weed control workers and other interested personnel from Cornell University, Rutgers, and Pennsylvania State University met with G.L.F. representatives and discussed prevalent weed control problems in the area.

R. D. Sweet, Dept. of Vegetable Crops, Cornell University will take sabbatical leave beginning February 1, 1956. He will spend several months in Florida and will then be associated with William Chappel at Virginia Polytechnical Institute for several additional months.

Bruce J. Rogers was added to the staff of the Dept. of Botany and Plant Pathology, Purdue University after completion of the requirements for a Ph.D. degree in plant physiology at the California Institute of Technology. He will be concerned mainly with physiological studies as they relate to weed control with particular emphasis on perennial weeds.

Lawrence O. Baker has assumed the responsibilities for weed control research and teaching at Montana State College. Mr. Baker recently completed his course work for the Ph.D. degree at the University of Minnesota.

Publications of the various weed control conferences can be obtained from the following sources. Inquiries as to the availability and costs of publications should be addressed to the conference secretaries.

Western Weed Control Conference

W. C. Robocker, Secretary-Treasurer
Weed Investigations Section, USDA
University of Nevada, Reno, Nevada.

North Central Weed Control Conference

D. W. Lambert, Secretary-Treasurer
Nebraska Dept. of Agric. and Inspection
Lincoln, Nebraska.

Northeastern Weed Control Conference

R. J. Aldrich, Secretary
Weed Investigations Section, USDA
Farm Crops Dept., Rutgers University
New Brunswick, New Jersey.

Southern Weed Conference
E. G. Rodgers, Secretary-Treasurer
Dept. of Agronomy, University of Florida
Gainesville, Florida.

Western Canadian Weed Control Conference
T. V. Beck, Secretary
Plant Industry Branch, Saskatchewan Dept. of Agriculture
Regina, Saskatchewan.

British Weed Control Conference
W. A. Williams, Secretary
Association of British Insecticide Manufacturers
Cecil Chambers, 86 Strand
London, W. C. 2, England.

The Eighth Illinois Custom Spray Operators' Training School was held on the campus of the University of Illinois at Urbana on January 26 and 27, 1956.

The Short Course for Weed and Seed Inspectors in the state of Minnesota was held at University Farm, St. Paul, during the week of January 16–20, 1956.

An announcement has been received of the recent appointment of L. M. Stahler to the position of Manager of the Agricultural Sales Division of the Pacific Coast Borax Co.

E. A. Helgeson was elected president, F. W. Slife vice president and D. W. Lambert secretary-treasurer of the North Central Weed Control Conference at the 1955 meeting held at Omaha, Nebraska on December 6–8. The 1956 meeting of the conference will be held at the Sherman Hotel in Chicago on December 10, 11 and 12.

Nearly 700 attended the charter meeting of the Weed Society of America which met in New York City January 4 and 5, 1956. Those in attendance included state and federal workers, representatives of industry, county agents, commercial sprayers, farmers and representatives from at least seven foreign countries. Seventy-nine papers were presented covering many aspects of weeds and their control. B. T. Shaw, Administrator, Agricultural Research Service, discussed the place of weed control in American agriculture during the opening session. The problems, progress and organization of weed control in England, in Canada and in the United States were reviewed by representatives of the respective countries as part of the first day's program. During the second day papers devoted to specific crops and situations were presented in nine separate sections. The next meeting of the Weed Society will be held in Memphis, Tennessee January 14, 15 and 16, 1958.

At the business meeting on January 4th the constitution for the Weed Society of America was formally adopted. The constitution is printed in full in this issue of WEEDS.

The members of the Society elected the following officers by mail Ballot: President, W. B. Ennis Jr.; Vice-President, A. S. Crafts; Secretary, W. C. Shaw.

SUSTAINING MEMBERS

American Chemical Paint Company, Ambler, Pennsylvania
American Smelting and Refining Company, So. Plainfield, New Jersey
Association of American Railroads, Chicago, Illinois
John Bean Division, Food Machinery & Chemical Corp., Lansing, Michigan
Carbide and Carbon Chemicals Company, New York, New York
Chipman Chemical Company, Inc., Bound Brook, New Jersey
The Dow Chemical Company, Midland, Michigan
E. I. duPont de Nemours & Co. Inc., Wilmington, Delaware
The Engine Parts Manufacturing Company, Cleveland, Ohio
G.L.F. Soil Building Service, Ithaca, New York
Hercules Powder Company, Wilmington, Delaware
Monsanto Chemical Company, St. Louis, Missouri
National Aluminate Corp., Chicago, Illinois
Oberdorfer Foundries Inc., Syracuse, New York
Olin Mathieson Chemical Company, Baltimore, Maryland
Penn Line Service, Inc., Scottdale, Pennsylvania
Pittsburgh Coke & Chemical Company, Pittsburgh, Pennsylvania
O. M. Scott and Sons Company, Marysville, Ohio
Spraying Systems Company, Bellwood, Illinois
Standard Agricultural Chemicals Inc., Hoboken, New Jersey
Swift and Company (Plant Food Division) Chicago, Illinois

Constitution of the Weed Society of America

ARTICLE I—Name

This organization shall be known as the Weed Society of America.

ARTICLE II—Objectives

The objectives of this Society shall be to:

1. Encourage and promote the development of knowledge concerning weeds and their control.
2. Publish the results of meritorious research and other information of value pertaining to weeds and their control.
3. Promote unity in education, legislation, regulation, terminology, and other matters pertaining to weeds.
4. Foster high standards in weed control education and to encourage its acceptance as a major field of training.
5. Promote high ethics and good fellowship among its members.
6. Aid the coordination of the activities and cooperate with member weed control conferences and to cooperate with other societies and organizations with similar and related interests.
7. Remain a scientific organization, without the object of financial gain.

ARTICLE III—Membership

Section 1.

The membership of the Society shall be open to individuals and organizations of all nations interested in the objectives of the Society. There shall be four types of membership: (1) Active, (2) Honorary, (3) Sustaining, and (4) Conference.

Section 2.

Active members are individuals who are interested in weeds or their control and who have remitted their annual dues to the Treasurer. Active members may attend all Society meetings, vote on all matters pertaining to the Society, and may hold office.

Section 3.

Honorary members are individuals who have contributed meritorious service to the study of or control of weeds and who are nominated by two-thirds of the entire membership of the Executive Committee and are elected by two-thirds of those voting by mail ballot at any regular election. Honorary members shall have the privileges of Active Members and may receive a publication of the Society for life. The awarding of Honorary membership at any one general meeting of the Society shall be limited to a number not to exceed one-fourth of one percent of the active membership.

Section 4.

Sustaining members shall consist of persons or organizations who are interested in the objectives of the Society and wish to participate in the work of the Society and have remitted their annual dues.

The names of such members shall be printed in all issues of the official publication of the Society and in the programs of the regular meetings. Each Sustaining member shall receive the Journal WEEDS.

Section 5.

Conference members shall consist of the Western, North Central, Southern and Northeastern Weed Control Conferences as Charter Conference Members. Any other Weed Control Conference may be admitted upon application to the Executive Committee and subsequent approval in the same manner as is required for amendments to the constitution.

ARTICLE IV—MEETINGS

Meetings of the Society shall be held at the time and place designated by the Executive Committee.

ARTICLE V—OFFICERS

Section 1.

The elected officers of the Society shall be a President, a Vice-President, and a Secretary. The duties of these officers shall be those usually performed by such officers.

Section 2.

The Executive Committee shall appoint a Treasurer-Business Manager of the Society to serve at the pleasure of that committee.

Section 3.

The elected officers shall begin their duties at the close of the meeting at which they are installed and shall remain in office until the close of the next Society meeting. The President and the Vice-President shall not be eligible to the same office a second time.

ARTICLE VI—ENDOWMENT FUNDS

Endowment funds for specific purposes may be established at any time by the Executive Committee subject to the provisions of the Constitution and the By-Laws of the Society. It is understood that the principle of the endowments funds shall be kept productively invested, only the incomes therefrom being available.

Bequests and gifts of funds or securities accepted without obligation by the Executive Committee shall be administered by the Executive Committee with due regard to the wishes of the donor.

ARTICLE VII—ELECTION OF OFFICERS

Section 1.

The Nominating Committee shall consist of one member from each member conference plus a chairman. The Executive Committee shall select the members and the chairman. The Nominating Committee shall present two names for the office of the President and two names for the office of Vice-President. The member receiving the highest number of votes for each office on the mail ballot shall be elected.

The Nominating Committee shall present one, or not more than three members as nominees for the office of Secretary. The nominee who receives the largest number of votes is elected.

Section 2.

No member's name shall be placed on the ballot by the Nominating Committee without his written consent.

Section 3.

Six weeks prior to each meeting, the ballots shall be mailed to those eligible to vote in the Society. All ballots received two weeks prior to the start of the meeting shall be counted by the Secretary and two other members of the Society appointed by the President.

Section 4.

If an officer cannot serve the full elected term, the vacancy shall be filled for the interim by an appointment by the Executive Committee.

ARTICLE VIII—STANDING COMMITTEES

Section 1.

There shall be eight standing committees: Executive, Program, Finance, Terminology, Editorial, Education, Legislative, and Public Relations. The President shall be an ex officio member of all committees. Committee members must be active members of the Society.

Section 2.

The Executive Committee shall consist of the President, (who shall be Chairman of this Committee), Vice-President, Secretary, Past President, and two members designated by each member weed conference. The Editor of WEEDS and Treasurer-Business Manager of the Society shall be ex officio members of the Executive Committee.

A quorum of the Executive Committee shall consist of a representative of each of a majority of the member weed conferences. Each conference shall have a minimum of two votes on the Executive Committee even though represented by only one member at any meeting.

Section 3.

The Program Committee shall consist of the Secretary, as Chairman, and four additional members to be appointed by the President.

Section 4.

The Finance Committee shall consist of a chairman and four members, appointed by the President, one each year for a term of five years.

Section 5.

The Terminology Committee shall consist of a Chairman and four members appointed by the President, one each year for a term of five years.

Section 6.

The Editorial Committee shall consist of the Editor and four members appointed by the Editor.

Section 7.

The Legislative Committee shall consist of a Chairman and four members appointed by the President, one each year for a term of five years.

Section 8.

The Education Committee shall consist of a Chairman and four members appointed by the President, one each year for a term of five years.

Section 9.

The Public Relations Committee shall consist of a chairman and four members appointed by the President to serve until a new President takes office.

ARTICLE IX—AUDITING OF ACCOUNTS

Accounts of the Treasurer-Business Manager and others entrusted with funds shall be audited annually by a qualified auditor or auditing committee.

The Auditor's reports shall be submitted to the Society at the general business meeting.

ARTICLE X—PUBLICATIONS

Section 1.

One or more publications may be published by the Society as authorized by the Executive Committee. Each publication shall be under the direction of an Editor who shall be appointed by the Executive Committee.

Section 2.

The official Journal of the Society shall be called WEEDS and shall carry all official notices, committee reports, and other items of Society business. The policies of the Journal shall be established jointly by the Executive Committee and the Editorial Committee Any member of the Society may contribute to the Journal. Acceptance of such contributions rests with the Editorial Committee.

ARTICLE XI—AMENDMENTS

Section 1.

Any Active member of the Society may initiate a proposed amendment to this Constitution. Such proposals. if approved by two-thirds of the entire Executive Committee, shall be included on the next ballot and sent to all members at the time of the election of officers.

Section 2.

Adoption of a proposed amendment shall require a two-thirds vote of those members voting on the amendment.

AUTHOR AND SUBJECT-TITLE INDEX FOR VOLUME I

PAGE

Africa, thorn scrub control with herbicides 372
Aldrich, Richard J. 338
Aliphatic hydrocarbons, effect on hypocotyls of cotton and soybean and shoots of nut grass, Johnson grass and other weeds 256
Aromatic solvents for control of submersed water weed naiad, *Najas guadalupensis* (Spreng.) Morong., in south Florida 366
Ball, Walter S. 13
Benzoic acids (substituted) and related compounds, plant hormone activity 185
Bibliography of weed investigations for; January, February, and March, 1951 75
April, May, June, 1951 99
July, August, and September, 1951 194
October, November, and December, 1951 289
January, February, and March, 1952 377
Book notes 193, 287
Broccoli and kale, selective herbicides for 189
Brush and roadside weed control 17
Brush, fogging with 2,4–D by helicopter 61
Buchholtz, K. P. 237, 346
Carriers, influence upon inhibitory properties of growth-regulatory sprays 43
Chilton, S. J. P. 32
Cogan and torpedo grass, a challenge 374
Control of roadside weeds and brush 17
Corn, pre-emergence treatment with 2,4–D 338
Cotton hypocotyls as affected by aliphatic hydrocarbons sprayed directionally 256
Crop growth as affected by soil physical properties, use of herbicides in study 174
Cultural methods for control of quackgrass 346
Derscheid, Lyle A. 329
Design and evaluation of a small-plot sprayer 160
Determinations of the effect of several herbicides on soil microorganisms 25
Directional spray technique used in studying effect of aliphatic hydrocarbons on hypocotyls and shoots of plants 256
Dorschner, K. P. 274
Effect of aliphatic hydrocarbons on hypocotyls of cotton and soybeans and shoots of nut grass, Johnson grass and other weeds by directional spray technique 256
Elle, George O. 141
Ennis, W. B., Jr. 43, 274
Environmental factors affecting the response of sweet corn to 2,4–D 141
Equipment used in evaluating chemicals for herbicidal properties 352
Erickson, C. 321
Euphorbia, identification of seeds of weedy species 243
Evaluating chemicals for herbicidal properties, techniques and equipment .. 352
Evaluation and design of a small-plot sprayer 160
Factors affecting pre-emergence use of 2,4–D in corn 338
Factors influencing herbicidal efficacy of isopropyl N phenyl carbamate 48
Florida, control of water weed naiad with aromatic solvents 366
Fogging Ribes, white pine, and brush with 2,4–D by helicopter 61
Freed, Virgil H. 48
Growth-regulatory sprays, influence of carriers upon inhibitory properties .. 43
Halogeton problem, present status 321
Hansen, J. R. 237
Harris, V. C. 256
Hattingh, E. R. 372
Havis, John R. 189
Helicopter used in fogging of Ribes, white pine, and brush with 2,4–D 61
Herbicidal efficacy of isopropyl N phenyl carbamate, influencing factors 48
Herbicides selective for kale and broccoli 189

PAGE

Herbicides; effect on soil microorganisms 25
a new tool for use in studying soil physical properties affecting crop growth 174
Identification of seeds of weedy Euphorbia species 243
Inactivation of 2,4–D by riboflavin in light 237
Influence of carriers upon inhibitory properties of growth-regulatory sprays 43
Inhibitory properties of growth-regulatory sprays as influenced by carriers.. 43
Isopropyl N phenyl carbamate, factors influencing herbicidal efficacy..... 48
Jacobson, H. G. M. 174
Johnson grass control in sugarcane 32
Johnson grass shoots as affected by aliphatic hydrocarbons sprayed directionally 256
Kale and broccoli, selective herbicides for 189
Kratochvil, D. E. 25
Krochmal, Arnold 243
Leaves, spray retention 274
Leonard, O. A. 256
Light and riboflavin for inactivation of 2,4–D 237
Lowe, H. J. 346
Microorganisms of the soil, determining effect of herbicides on 25
Miller, Harold J. 185
Morton, H. L. 321
Naiad, control in Florida with aromatic solvents 366
Najas guadalupensis (Spreng.) Morong., control in Florida with aromatic solvents 366
Nut grass shoots as affected by aliphatic hydrocarbons sprayed directionally.. 256
Offord, H. R. 61
Plant hormone activity of substituted benzoic acids and related compounds 185
Pre-emergence use of 2,4–D in corn 338
Present status of the Halogeton problem 321
Quackgrass control by cultural methods 346
Randolph, John W. 366
Regulatory phase of weed control 13
Retention of spray by plant leaves 274
Ribes, fogging with 2,4–D by helicopter 61
Riboflavin in light for inactivation of 2,4–D 237
Ries, S. K. 160
Roadside weed and brush control 17
Seale, Charles C. 366
Seeds of weedy Euphorbia species, identification 243
Shaw, W. C. 352
Soil microorganisms, determining effect of herbicides on 25
Soil physical properties affecting crop growth, use of herbicides in study.... 174
Soybean hypocotyls as affected by aliphatic hydrocarbons sprayed directionally 256
Sprayers for use on experimental plots 329
Sprayer, small-plot, design and evaluation 160
Spray retention by plant leaves 274
Stamper, E. R. 32
Stephens, John C. 366
Studies on spray retention by plant leaves 274
Sugarcane, Johnson grass control in 32
Swanson, C. L. W. 174
Swanson, C. R. 352
Sweet corn response to 2,4–D as affected by environmental factors 141
Sylwester, E. P. 17
Tabor, Paul 374
Techniques and equipment used in evaluating chemicals for herbicidal properties 352
Terry, C. W. 160
Thorn scrub control with herbicides in Africa 372
Tisdale, E. W. 321
Torpedo grass and Cogon, a challenge 374

PAGE

2,4–D; fogged on Ribes, white pine, and brush 61
inactivation by riboflavin in light 237
pre-emergence use in corn 338
response of sweet corn as affected by environmental factors 141
Voss, C. M. 61
Water weed naiad, control in Florida with aromatic solvents 366
Weed control, regulatory phase 13
Where do we go from here? 9
White pine, fogging with 2,4–D by helicopter 61
Willard, C. J. 9, 338
Williamson, Ralph E. 274
Woodward, Carol H. 193, 287
Zappettini, Geo. 321

AUTHOR AND SUBJECT-TITLE INDEX FOR VOLUME II

PAGE

Action of isopropyl N-phenyl carbamate under various conditions..... 169
Ahlgren, Gilbert H. 27
Aldrich, Richard J. 27, 202, 262
Baskin, A David 280
Benzoic acid derivatives, failure of light activated riboflavin to counteract inhibition 202
Bibliography of weed investigations for; April, May, and June, 1952..... 68
July, August, September, 1952 84
October, November, and December, 1952 159
January, February, and March, 1953 205
April, May, and June, 1953 305
Blouch, Roger 119
Book review 303
Botanical composition of Ladino clover-orchard grass pasture as affected by 2,4–D 105
Brown, D. A. 295
Brown, J. W. 288
Bruns, V. F. 138
Canada thistle seed germination as affected by fresh water storage..... 138
Carbamates and other chemicals, relation of structural configuration to herbicidal properties and phytotoxicity 43
Carriers, influence upon inhibitory effectiveness of 2,4–D 33
C^{14} Carbonyl labeled 3–(parachlorophenyl)–1, 1–dimethylurea synthesized.... 135
C^{14}, use in leaching studies with isopropyl N–phenyl carbamate 24
Chamblee, D. S. 105
Chemicals for crabgrass control in turf 27
Chloro-IPC; distribution in soil 300
influence of soil type on selective action 119
selective mechanism theory 155
CMU; effect on nutgrass 196
synthesis with C^{14} carbonyl label 135
Comparison of five chemicals for crabgrass control in turf 27
Connecticut River Valley, Mass., weed populations as related to cultivated crops 125
Connell, C. R. 288
Cotton seeds, germinating, as affected by CIPC and DNBP 178
Crabgrass control in turf with chemicals 27
Cruzado, H. J. 196
Cultivated crops as related to weed populations in Connecticut River Valley 125
Cultural control of wild oats 295
Cyperus rotundus L., effects of CMU on 196
Dean, E. W. 288
DeRigo, H. T. 169
Dinitro ortho secondary butyl phenol, alkanolamine salt, effects on germinating cotton seeds 178
Distribution of CIPC in soil 300
Effect of CMU on nutgrass *(Cyperus rotundus* L.) 196
Effect of fresh water storage on germination of weed seeds..... 138
Effect of maleic hydrazide on soil bacteria and other microorganisms..... 190
Effect of isopropyl N–(3–chlorophenyl) carbamate and an alkanolamine salt of dinitro ortho secondary butyl phenol on germinating cotton seeds.... 178
Effect of sodium 2,4–dichlorophenoxyethyl sulfate on growth and yield of strawberries 262
Effect of 2,4–D; on growth of young sugar cane 148
on yield and botanical composition of Ladino clover-orchard grass pasture 105
Elwell, Harry M. 302
Engel, Ralph E. 27
English, A. R. 190

PAGE

Failure of light activated riboflavin to counteract growth inhibition of benzoic acid derivatives 202
Florida, control of para grass in Everglade region 15
Freed, V. H. 24
Fults, Jess 119
Gangstad, Edward O. 113
Germinating cotton seeds as affected by CIPC and DNBP 178
Germination of weed seeds as affected by fresh water storage 138
Gertsch, Milton E. 33
Great plains region of North America, wild oats problem 292
Growth of young sugar cane, effect of 2,4–D 148
Growth regulants, volatility determinations by response of tomato plants.... 254
Growth regulators of plants—halogenated phenyl alkyl ethers..... 288
Halogenated phenyl alkyl ethers as plant growth regulators 288
Hamilon, Robert H. 202
Hamner, C. L. 271
Hauser, Ellis W. 105
Havis, John R. 148
Herbicidal properties of carbamates and other chemicals, relation to structural configuration 43
Herbicidal tests for control of para grass on ditch banks in Florida..... 15
Herbicides for control of weeds in sansevieria 113
Hitchcock, A. E. 254
Hoffman, Otto L. 66
Howard, W. H. 288
Hughes, J. H. 178
Influence of carriers upon inhibitory effectiveness of 2,4–D sprays..... 33
Influence of soil type on selective action of chloro-IPC and sodium TCA.. 119
Inhibition of growth by benzoic acid derivatives, failure of light activated riboflavin to counteract 202
Inhibitory effectiveness of 2,4–D as influenced by carriers 33
Isleib, Donald R. 262
Isopropyl N–(3–chlorophenyl) carbamate, effects on germinating cotton seed.. 178
Isopropyl N–phenyl carbamate; action under various conditions..... 169
leaching rate studies using C^{14} 24
Joyner, J. Frank 113
Kaufman, Peter B. 223
Kirkpatrick, Henry, Jr. 254
Ladino clover-orchard grass pasture, effect of 2,4–D on yield and botanical composition 105
Leaching rate of isopropyl N–phenyl carbamate, studies using C^{14}..... 24
Logan, Albert V. 24, 135
Loustalot, A. J. 196
Maleic hydrazide; effect on soil bacteria and other microorganisms..... 190
for quackgrass control 66
McLane, S. R. 288
Methods for determining relative volatility of 2,4–D and other growth regulants by response of tomato plants 254
Microorganisms as affected by maleic hydrazide 190
Minarik, C. E. 288
Morning glory seed germination as affected by fresh water storage..... 138
Morphological responses of rice to 2,4–D 223
Muzik, T. J. 196
Native grass production increased by herbicidal control of oak brush..... 302
New herbicide controlled oak brush and resulted in increased native grass production 302
Newman, A. S. 169
Nickell, L. G. 190
Nutgrass, effects of CMU 196
Oak brush controlled by new herbicide 302
Occurrence and problem of wild oats in the great plains of North America.. 292
Odell, Norman R. 24, 135

PAGE

Orchard grass-Ladino clover, effect of 2,4–D on yield and botanical composition 105
Para grass control on ditch banks in Florida Everglades 15
Pasture, Ladino clover-orchard grass, effect of 2,4–D on yield and botanical composition 105
Persistence of sodium trichloroacetate in different soil types 271
Phytotoxicity of carbamates and other chemicals, relation to structural configuration 43
Population of weeds as related to cultivated crops in Connecticut River Valley 125
Poverty weed seed germination as affected by fresh water storage..... 138
Pray, Blaine O. 300
Preliminary studies on use of herbicides for control of weeds in sansevieria.. 113
Quackgrass control with maleic hydrazide 66
Rai, G. S. 271
Rasmussen, L. W. 138
Relation of structural configuration to herbicidal properties and phytotoxicity of several carbamates and other chemicals 43
Responses of tomato plants to vapors of 2,4–D or 2,4,5–T formulations at different temperatures 280
Riboflavin, light activated, failure to counteract growth inhibition of benzoic acid derivatives 202
Rice, morphological responses to 2,4–D 223
Ries, S. K. 155
Robocker, W. C. 303
Russian knapweed seed germination as affected by fresh water storage..... 138
Sansevieria, control of weeds with herbicides in 113
Seale, Charles C. 113
Selective action of chloro-IPC and sodium TCA as influenced by soil type.. 119
Selective mechanism theory for chloro-IPC 155
Shaw, W. C. 43, 105, 178
Soil bacteria as affected by maleic hydrazide 190
Soil, distribution of CIPC in 300
Soil type; influence on selective action of chloro-IPC and sodium TCA..... 119
persistence of sodium trichloroacetate 271
Speir, William H. 15
Stephens, John C. 15
Storage in fresh water, effects on germination of weed seeds 138
Strawberry growth and yield as affected by sodium 2,4–dichlorophenoxyethyl sulfate 262
Structural configuration of carbamates and other chemicals, relation to herbicidal properties and phytotoxicity 43
Sugar cane, effect of 2,4–D on growth 148
Swanson, C. R. 43, 178
Sylwester, E. P. 66
Synthesis of C^{14} carbonyl labeled 3–(parachlorophenyl)–1, 1–dimethylurea.. 135
TCA, sodium, influence of soil type on selective action 119
Temperature, influence on responses of tomato plants to vapors of 2,4–D or 2,4,5–T 280
Theory for selective mechanism of chloro-IPC 155
3–(parachlorophenyl)–1, 1–dimethylurea synthesis with C^{14} carbonyl label.. 135
Tomato plants, response to vapors of 2,4–D or 2,4,5–T 280
Tomato plants used to determine volatility of 2,4–D esters and other growth regulants 254
Trichloroacetate, sodium, persistence in soil 271
Turf, control of crabgrass with chemicals 27
2,4–D; effect on growth of young sugar cane 148
effect on yield and botanical composition of Ladino clover-orchard grass pasture 105
inhibitory effectiveness as influenced by carriers 33
morphological effects on rice 223
2,4–D esters, volatility determinations by response of tomato plants..... 254
2,4–D vapors, tomato plant response at different temperatures..... 280

PAGE
2,4–dichlorophenoxyethyl sulfate, sodium, effect on growth and yield of strawberries 262
2,4,5–T vapors, tomato plant response at different temperatures 280
Use of C^{14} in studying leaching rate of isopropyl N–phenyl carbamate 24
Vengris, Jonas 125
Volatility determinations of 2,4–D esters and other growth regulants by response of tomato plants 254
Walker, E. A. 280
Weed control in sansevieria with herbicides 113
Weed populations as related to cultivated crops in Connecticut River Valley 125
Weed seeds, effects of fresh water storage on germination 138
White top seed germination as affected by fresh water storage 138
Wild oats; in great plains of North America 292
progress in cultural control 295
Witman, Eugene D. 300
Wood, H. E. 292
Woodhouse, W. W., Jr. 105
Yield of Ladino clover-orchard grass pasture as affected by 2,4–D 105
Zimmerman, P. W. 254

AUTHOR AND SUBJECT-TITLE INDEX FOR VOLUME III

PAGE

Accumulation and distribution of TCA in plant tissues 146
Activity of herbicides in soils 257
Amino acid derivatives of 2-methyl-4-chlorophenoxyacetate, plant-growth modifiers 28
Analysis and design in chemical weed control research 152
Andersen, Robert N. 351
Annual grasses, pre-emergence control with chlordane, chlorobromopropene, and hexachlorocyclopentadiene 377
Annual weed control with herbicides in onion seed crops 345
Aquatic weed control in western irrigation waters 231
Aquatic weed problems in wildlife habitat 139
Aspects of right-of-way brush control with 2,4,5-T and 2,4-D 21
Avena fatua, selective control with IPC and CIPC 321
Ball, Walter S. 38
Barberry killed with herbicides 123
Beans, Red Mexican, response to 2,4-D in irrigation water 359
Bibliography of weed investigations for; July, August, and September, 1953.. 83
October, November, and December, 1953 209
January, February, and March, 1954 293
April, May, and June, 1954 389
Blanchard, F. A. 274
Blended solvents for control of submersed water weed naiad in Florida.... 160
Blondeau, Rene 55
Blouch, Roger M. 377
Brown, James W. 171
Bruns, V. F. 359
Brush control with 2,4,5-T and 2,4-D 21
Buchholtz, K. P. 331
C^{14} labeled TCA, uptake, distribution and metabolism in corn and pea plants 274
Chemical and physical properties of weed killers 241
Chemicals, evaluation for weed control in strawberries 192
Chemicals tested for herbicidal properties, species sensitivity 171
Chemical weed control research, design and analysis 152
Chlordane, chlorobromopropene, and hexachlorocyclopentadiene for pre-emergence control of crabgrass and other annual grasses 377
Chlorobromopropene for pre-emergence control of crabgrass and other annual grasses 377
CIPC, preplanting applications for selective control of wild oats 321
Control of aquatic weeds that impede flow of western irrigation waters.... 231
Corn plants, uptake, distribution, and metabolism of C^{14} TCA..... 274
Cotton, isopropyl N-(3-chlorophenyl) carbamate as selective pre-emergence herbicide 282
Coulter, L. L. 21
Crabgrass, pre-emergence control with chlordane, chlorobromopropene, and hexachlorocyclopentadiene 377
Craig, A. L. 160
Dalapon; as a protein precipitant 387
post-emergence applications to wild oats 351
Davis, Franklin L. 11
Dean, E. W. 75
Design and analysis in chemical weed control research 152
Digitaria sanguinalis L., pre-emergence control with chlordane, chlorobromopropene, and hexachlorocyclopentadiene 377
Dinitro weed killer movement in soils 11
Distribution of C^{14} labeled TCA in corn and peas 274
Drake, T. F. 28
Dunham, R. S. 321
Dybing, C. Dean 377

PAGE

Effectiveness of isopropyl N–(3–chlorophenyl) carbamate as pre-emergence herbicide in cotton ... 282
Effect of trichloroacetate on intake of nutrients by wheat plants at different fertility levels ... 254
Effects of post-emergence applications of dalapon to wild oats ... 351
Effects of water upon movement of dinitro weed killers in soils ... 11
Environment control chamber for herbicide research ... 143
Enzyme systems influenced by 2,4–D ... 131
Evaluation of several chemicals for weed control in strawberries ... 192
Extension program in weed control ... 188
Extension weed specialist, responsibilities ... 45
Extension work in weed control ... 49
Factors affecting tolerance of peas to MCP and other growth regulators ... 331
Fate and activity of herbicides in soils ... 257
Fertility level influence on effect of TCA on intake of nutrients by wheat plants ... 254
Florida, control of water weed naiad ... 160
Florida Everglades, weed control in onions ... 66
Fontaine, T. D. ... 28
Foy, Chester L. ... 282
Fults, Jess L. ... 377
Growth regulating compounds, toloxyacetic acids ... 279
Growth regulating herbicides, factors affecting tolerance of peas ... 331
Guzman, V. L. ... 66
Hamaker, John ... 387
Hamner, C. L. ... 254
Harvey, W. A. ... 45
Haun, J. R. ... 177
Hawthorn, L. R. ... 345
Helgeson, E. A. ... 351
Herbicidal methods for control of annual weeds in onion seed crops ... 345
Herbicidal properties of chemicals, species sensitivity ... 171
Herbicide research, controlled-environment chamber ... 143
Herbicides; fate and activity in soils ... 257
for killing barberry ... 123
Hexachlorocyclopentadiene for pre-emergence control of crabgrass and other annual grasses ... 377
Holm, LeRoy G. ... 146
Hormone-type herbicides for killing barberry ... 123
Identification of weed plants and seeds, teaching aids ... 342
Inexpensive controlled-environment chamber for herbicide research ... 143
Influence of 2,4–D on enzyme systems ... 131
IPC, preplanting applications for selective control of wild oats ... 321
Irrigation water containing 2,4–D, response of crops ... 359
Irrigation waters, control of aquatic weeds ... 231
Isopropyl N–(3–chlorophenyl) carbamate, selective pre-emergence herbicide in cotton ... 282
Jacob, W. C. ... 152
Kepner, P. V. ... 49
Killing native barberry with hormone-type herbicides ... 123
Krewson, C. F. ... 28
Lee, Oliver C. ... 136
Lee, W. O. ... 345
Leinweber, Charles L. ... 143
Lungren, E. A. ... 123
Marsh and aquatic weed problems in wildlife habitat ... 139
Martin, Alexander C. ... 139
McCully, Wayne G. ... 143
McLane, S. R. ... 75
MCP, factors affecting tolerance of peas ... 331
Melander, L. W. ... 123
Metabolism of C^{14} labeled TCA in corn and peas ... 274

PAGE
Minarik, C. E. 75, 279
Mitchell, J. W. 28
Mode of action of phytotoxic oils 55
Modifiers of plant-growth, amino acid derivatives of 2-methyl-4-chlorophenoxyacetate 28
Naiad control with blended solvents in Florida 160
Neufeld, C. H. H. 28
New growth regulating compounds, toloxyacetic acids 279
Nex, R. W. 241
Nutrient intake by wheat plants, effect of sodium TCA 254
Oborn, Eugene T. 231
Ogle, R. E. 257
Oils, phytotoxic, mode of action 55
Onions and weed control in Florida Everglades 66
Onion seed crops, herbicidal methods for control of annual weeds 345
Organic soil of Florida Everglades, weed control in onions 66
Oshtemo sand, intake of nutrient studies 254
Pea plants, uptake distribution, and metabolism of C^{14} TCA 274
Peas, factors affecting tolerance to MCP and other growth regulators 331
Peterson, J. H. 177
Physical and chemical properties of weed killers 241
Phytotoxic oils, mode of action 55
Plant-growth modifiers, 2-methyl-4-chlorophenoxyacetyl derivatives of amino acids 28
Plant tissues, accumulation and distribution of TCA 146
Post-emergence application of dalapon to wild oats 351
Precision sprayer for small plots 75
Pre-emergence control of crabgrass and other annual grasses with chlordane, chlorobromopropene, and hexachlorocyclopentadiene 377
Pre-emergence herbicide in cotton, isopropyl N-(3-chlorophenyl) carbamate 282
Preplanting applications of IPC and CIPC for selective control of wild oats 321
Preston, W. H., Jr. 28
Protein precipitant, dalapon 387
Rai, G. S. 254
Ready, D. 279
Redemann, Carl T. 387
Regulatory aspects in weed control 38
Research in chemical weed control, design and analysis 152
Response of crops to 2,4-D in irrigation water 359
Responsibilities of an extension weed specialist 45
Ries, S. K. 152
Right-of-way brush control with 2,4,5-T and 2,4-D 21
Ruppenthal, R. U. 192
Scott, D. H. 192
Seale, Chas. C. 160
Selective control of wild oats, preplanting applications of IPC and CIPC 321
Selman, Frank L. 11
Shaw, W. C. 192
Small plot sprayer 75
Soils; fate and activity of herbicides 257
movement of dinitro weed killers affected by water 11
Species sensitivity to chemical tested for herbicidal properties 171
Sprayer for small plots 75
Statewide extension program in weed control 188
Stephens, John C. 160
Strawberry fields, evaluation of chemical for weed control 192
Swezey, A. W. 241
Synthetic plant-growth modifiers, 2-methyl-4-chlorophenoxyacetyl derivatives of amino acids 28
TCA, accumulation and distribution in plant tissues 146
Teaching aids in weed plant and seed identification 342
Teaching trends in weed control 136

PAGE

3–(p–chlorophenyl)–1, 1–dimethylurea, translocation in plants 177
Throne, J. Arthur 171
Tibbitts, Theodore W. 146
Timmons, F. L. 345
Toloxyacetic acids, new growth regulators 279
Translocation of 3–(p–chlorophenyl)–1, 1–dimethylurea in plants 177
Trends in teaching weed control 136
Trichloroacetate; C^{14} labeled, uptake, distribution and metabolism in corn and pea plants 274
  sodium, effect on intake of nutrients by wheat plants 254
2,4–D in irrigation water, response of crops 359
2,4–D; influence on enzyme systems 131
  right-of-way brush control 21
2,4,5–T, right-of-way brush control 21
2–methyl–4–chlorophenoxyacetyl derivatives of amino acids, plant-growth modifiers 28
2,2–dichloropropionic acid as a protein precipitant 387
Uptake of C^{14} labeled TCA in corn and pea plants 274
van Overbeek, J. 55
Warren, G. F. 257
Water, movement of dinitro weed killers in soils 11
Water weed naiad control, use of blended solvents 160
Watson, W. M. 123
Weed control in onions in organic soil of Florida Everglades 66
Weed control in strawberries, evaluation of chemicals 192
Weed control research with chemicals, design and analysis 152
Weed control; extension work 49
  regulatory aspects 38
  statewide extension program 188
  teaching trends 136
Weed killers, chemical and physical properties 241
Weed seed and plant identification, teaching aids 342
Wheat plants, intake of nutrients as affected by sodium TCA 254
Widdifield, R. B. 188
Wiese, A. F. 321
Wilson, Lloyd R. 342
Wildlife habitat, marsh and aquatic weed problems 139
Wild oats; effects of post-emergence applications of dalapon 351
  selective control with IPC and CIPC 321
Wolf, E. A. 66
Wort, D. J. 131